

M68332BCC/D
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M68332BCC
BUSINESS CARD COMPUTER
USER'S MANUAL

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CHAPTER 1

GENERAL INFORMATION

1.1 INTRODUCTION

This manual provides general information, hardware preparation, installation instructions, functional description, and support information for the M68332BCC Business Card Computer (hereafter referred as BCC). Appendix A contains BCC downloading S-record information.

1.2 FEATURES

The BCC is a single-board computer complete with these features:

- MC68332 Microcontroller Unit (MCU)
- 64k x 16 bit, two erasable programmable read only memories (EPROMs). Programmed into the BCC EPROMs is the M68CPU32BUG Debug Monitor. Refer to the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1.
- 32k x 16 bit, byte addressable random access memory (RAM)
- RS-232C compatible terminal/host computer input/output (I/O) port
- Background mode interface port
- EVS expansion connectors
- 2.25 x 3.875 in. (5.7 x 9.84 cm) PCB

The BCC can be used as a stand-alone evaluation module or can be connected directly to a target system. The BCC is primarily intended to be used with a terminal or host computer. When using a host computer, a user must have a terminal emulation package for BCC downloading operations.

1.3 SPECIFICATIONS

Table 1-1 lists the BCC specifications.

Table 1-1. BCC Specifications

CHARACTERISTICS	SPECIFICATIONS
Internal Clock External Clock	32.768 kHz 25 kHz to 50 kHz ⁽¹⁾
Memory 32k x 16 RAM 64k x 16 EPROM	85ns (3 clock bus cycle access @ 16.7 MHz) 200ns (5 clock bus cycle access @ 16.7 MHz)
Terminal/Host I/O Port	RS-232C compatible (with internal DC-DC converters for +/-10 volts, 10 mA)
Temperature Operating Storage Relative humidity	+25° C -40 to +85° C 0 to 90% (non-condensing)
Power Requirements Power Supply Battery Backup	+5 Vdc @ 200 milliamps (min.) +3 Vdc @ 50 microamps (min.)
Dimensions	2.25 x 3.875 in. (5.7 x 9.84 cm)

1. An optional high frequency clock source (as high as 16.77 MHz) may be used if MODCK (P2, pin 28) is pulled to a logic low level. A hybrid oscillator is recommended as the external clock.

1.4 GENERAL DESCRIPTION

Using the BCC, the user can design, debug, and evaluate MC68332 Microcontroller Unit (MCU) based target systems. The BCC simplifies user evaluation of prototype hardware/software products. The BCC requires a user-supplied power supply and an RS-232C compatible terminal for functional operation.

The BCC can operate as a standalone single board computer, or as a well-defined core in larger applications. Mounted on the BCC is a microcontroller, on-board memory, and a serial level converter circuit.

Two 64-pin expansion connectors provide access to the MC68332 pins. Background mode operation and RS-232C serial communication are available through the 64-pin expansion connectors. Additional connectors also provide background mode operation and RS-232C serial communication. See Chapter 5 for interface connector pin assignments.

The BCC is factory tested and shipped with factory installed jumpers. These jumpers allow the user to customize the BCC functionality when special design considerations are required.

The M68CPU32BUG Debug Monitor (CPU32Bug) is programmed into the BCC EPROMs. CPU32Bug is a software evaluation and debug tool which may be used to develop systems built around the MCU. Using the debug monitor, the user interacts with the BCC through pre-defined monitor commands which are entered at the terminal/host computer keyboard. These commands perform functions such as modification of memory, modification of MCU internal registers, program execution under various levels of control, and access to various I/O peripherals in the MCU itself.

To program the BCC EPROMs you must remove the EPROMs and use an EPROM programmer.

1.5 EQUIPMENT REQUIRED

Table 1-2 lists the external equipment requirements for BCC operation.

Table 1-2. External Equipment Requirements

EXTERNAL EQUIPMENT
A terminal or host computer (RS-232C compatible) with a terminal emulation package (PCKERMIT, PROCOMM, MacTerminal, White Knight, etc.) ⁽¹⁾
RS-232C serial communication cable for the terminal or host computer ⁽²⁾ .
+5 Vdc at 200 mA power supply ⁽²⁾

1. Refer to Chapter 3 for details on downloading using a host computer with terminal emulation package.
2. Refer to Chapter 2 for details.

CHAPTER 2

HARDWARE PREPARATION AND INSTALLATION

2.1 INTRODUCTION

This chapter provides unpacking instructions, hardware preparation, and installation instructions for the BCC prior to target system installation. This description ensures the BCC is properly configured for target system operation.

2.2 UNPACKING INSTRUCTIONS

Unpack the BCC from shipping carton. Refer to the packing list and verify that all items are present. Save packing material for storing and shipping the BCC.

NOTE

If the product arrives damaged, save all packing material, and contact the carrier's agent.

2.3 HARDWARE PREPARATION

This portion of text describes the inspection and preparation of the BCC prior to installation and ensures the proper configuration for target system operation. The BCC was factory tested and shipped with factory-installed jumpers (Figure 2-1 shows jumper header and connector locations). These jumper headers allow the user to customize BCC functionality. Table 2-1 is a description of the BCC jumper header types, and Table 2-2 is a summary of the BCC jumper headers.

CAUTIONS

Use caution when handling the BCC; the signals are not buffered so the BCC is sensitive to static discharge.

Depending on the application, it may be necessary to cut wiring trace shorts (cut-trace shorts) on the PCB. Be careful not to cut adjacent PCB wiring traces.

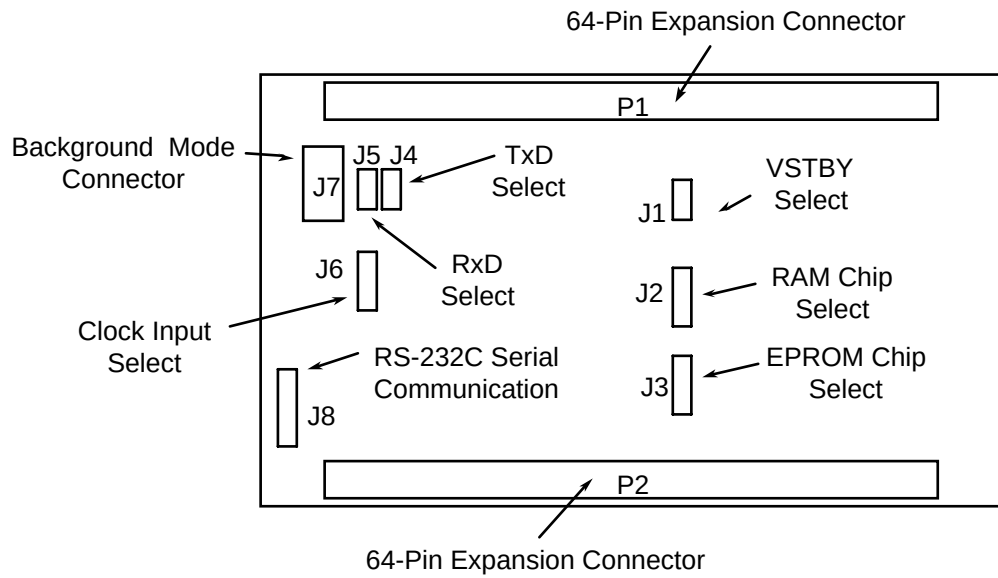


Figure 2-1. BCC Jumper Header and Connector Location Diagram

Table 2-1. Jumper Header Types

Jumper Header Type ⁽¹⁾	Symbol	Description
three-pin with jumper		Three-pin jumper header with jumper and designated as JX (X = the jumper header number). To change the factory jumper header configuration, move the jumper to the two desired pins.
two-pin with jumper		Two-pin jumper header with jumper, designated as JX (X = the jumper header number).

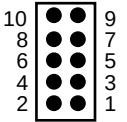
1. J7 and J8 are designated as jumper headers but they are in fact connectors.

Table 2-2. Jumper Header Summary

Jumper Header	Type	Description
J1 ⁽¹⁾	 2 1	Jumper between pins 1 and 2 (factory default); disables (grounds) the on-board RAM (U1 & U3) voltage standby power (VSTBY) input pin. VSTBY maintains the data in RAM if BCC power (+5Vdc) is turned off. No jumper; enables the on-board RAM VSTBY function. The VSTBY voltage must be supplied by the user.
J2 ⁽¹⁾	 3 2 1	Jumper between pins 1 and 2 (factory default); enables the on-board RAM chips (U1 & U3). Jumper between pins 2 and 3; disables the on-board RAM chips. This allows the chip select to be used with off-board memory.
J3 ⁽¹⁾	 3 2 1	Jumper between pins 1 and 2 (factory default); enables the on-board EPROM at U2. Jumper between pins 2 and 3; disables the on-board EPROM at U2. This allows the chip select to be used to boot from off-board memory.
J4 ⁽¹⁾	 2 1	Jumper between pins 1 and 2 (factory default); connects the on-board transmit data serial communication drivers to the MC68332 MCU device. No jumper; disconnects the on-board transmit data serial communication drivers from the MC68332 MCU device. This allows connection of the MCU serial port to off board logic.

1. These jumper headers are shorted by a trace on the solder side of the PCB (between the pins), as shown in the schematics. Cut the trace when using the optional feature provided by the jumper.

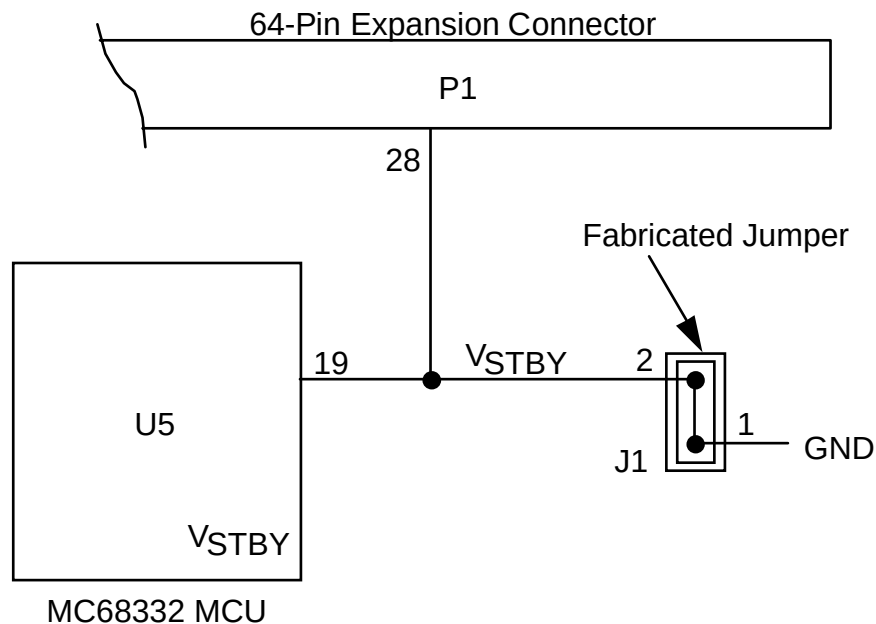
Table 2-1. Jumper Header Summary (continued)

Jumper Header	Type	Description
J5 ⁽¹⁾	 2 1	Jumper between pins 1 and 2 (factory default); connects the on-board receive data serial communication drivers to the MC68332 MCU device. No jumper; disconnects the on-board receive data serial communication drivers from the MC68332 MCU device. This allows connection of the MCU serial port to off board logic.
J6 ⁽¹⁾	 3 2 1	Jumper between pins 1 and 2; selects an external clock source for the MC68332 MCU device. Jumper between pins 2 and 3 (factory default); selects the on-board oscillator as the MC68332 MCU device clock source.
J7		10-pin background mode connector.
J8	 4 3 2 1	4-pin RS-232C serial connector.

1. These jumper headers are shorted by a trace on the solder side of the PCB (between the pins), as shown in the schematics. Cut the trace when using the optional feature provided by the jumper.

2.3.1 VSTBY Select Header (J1)

Use the two-pin jumper header J1 (shown below) to select a voltage standby (VSTBY) power supply source. VSTBY provides battery backup to the RAM contained in the MC68332 MCU device. The BCC is shipped from the factory with VSTBY connected to ground (GND) via J1 cut-trace short. To power VSTBY with an external supply, cut the trace on the bottom of the PCB and connect an external power supply between P1, pin 28 and any BCC ground pin. Refer to the BCC schematic diagram for more detail on VSTBY signal wiring.

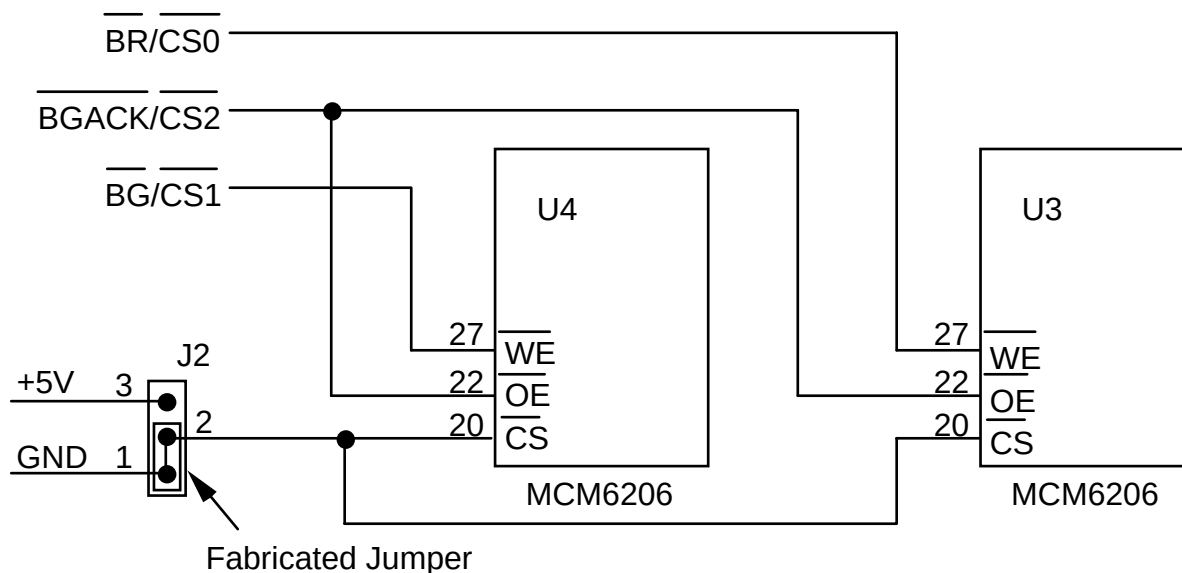


NOTE

If the cut-trace short on jumper header J1 is cut, a user-supplied fabricated jumper must be installed on J1 to return the BCC to its default setting.

2.3.2 RAM Chip Enable Select Header (J2)

Use the three-pin jumper header J2 (shown below) to enable/disable selection of the on-board RAM. The BCC is shipped from the factory with the RAM chip select connected to GND via a cut-trace short on the bottom of the BCC PCB between pins 1 and 2. A fabricated jumper is also installed between pins 1 and 2. The cut-trace short or a fabricated jumper between pins 1 and 2 enables the BCC on-board RAM.



To disable the RAM from the BCC memory map, cut the trace on the solder side of the board on J2, between pins 1 and 2, and move the fabricated jumper to pins 2 and 3. This jumper disables selection of the on-board RAM by connecting chip enable to +5V. The chip selects are now free for other uses. Refer to the BCC schematic diagram for more detail on RAM chip select signal wiring.

CAUTION

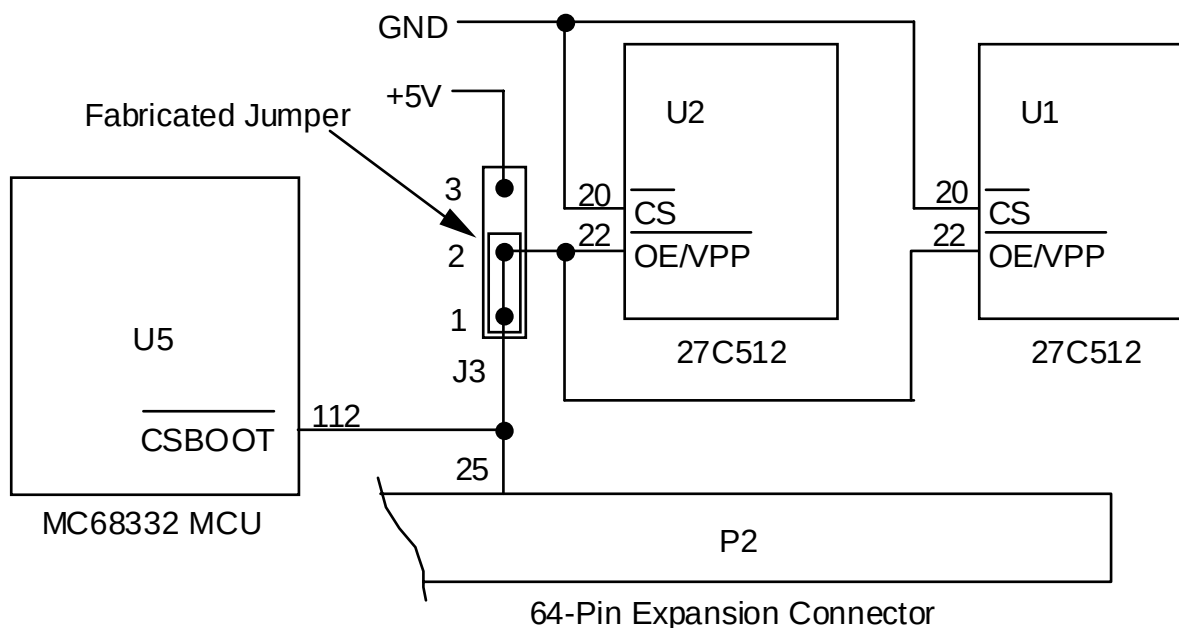
Do not connect the jumper between pins 2 and 3 before removing the cut-trace short between pins 1 and 2. Installing the jumper before the cut-trace short is removed connects +5Vdc to ground. If +5Vdc is shorted to ground the BCC or power supply may be damaged.

NOTE

If the cut-trace short on jumper header J2 is cut, the fabricated jumper must be reinstalled on J2, pins 1 and 2 to return the BCC to its default setting.

2.3.3 EPROM Chip Select Header (J3)

When BCC power is applied or reset occurs, the MC68332 MCU device resets itself and downloads the program in EPROM (U1 & U2). The EPROM contains the boot program. Use the three-pin jumper header J3 (shown below) to disable the BCC on-board EPROM. The BCC is shipped from the factory with the EPROM connected to the MCU bootstrap chip select pin (CSBOOT) via a cut-trace short on the bottom of the BCC PCB between pins 1 and 2. A fabricated jumper is also installed between pins 1 and 2. To boot from a program stored in memory located in the target system, cut this trace, move the jumper to pins 2 and 3, and connect CSBOOT to the target system via P2, pin 25. Cutting the cut-trace short and moving the fabricated jumper to pins 2 and 3, removes U1 & U2 from the BCC memory map. Refer to the BCC schematic diagram for more detail on CSBOOT signal wiring.



CAUTION

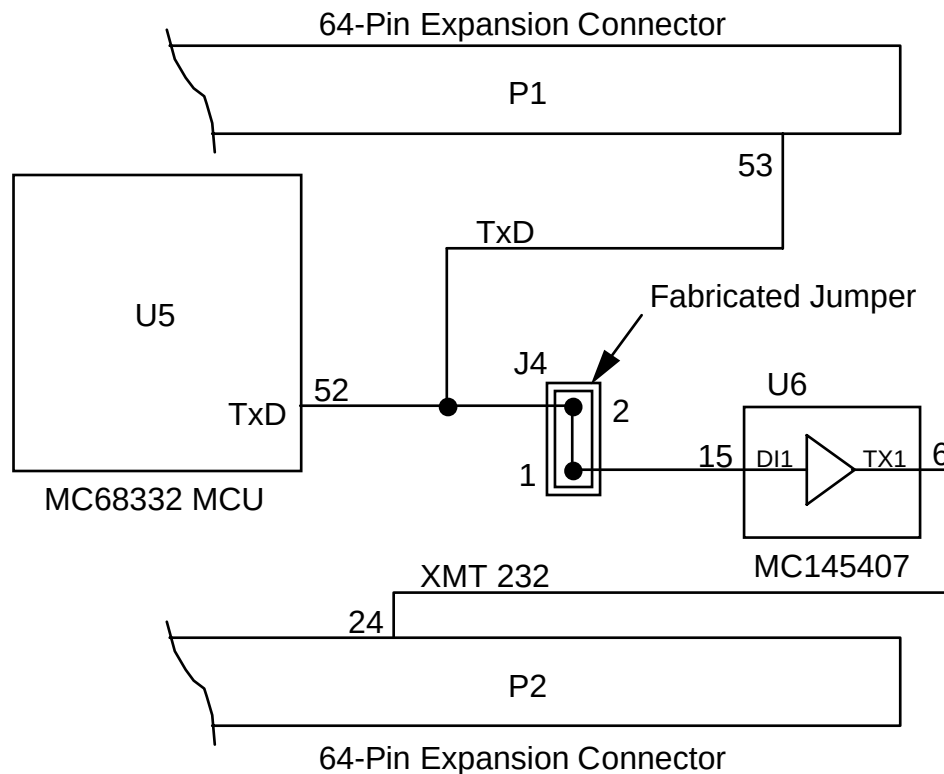
Do not connect the jumper between pins 2 and 3 before removing the cut-trace short between pins 1 and 2. Installing the jumper before the cut-trace short is removed connects +5Vdc to (CSBOOT). If +5Vdc is shorted to (CSBOOT) the MCU may be damaged.

NOTE

If the cut-trace short on jumper header J3 is cut, the fabricated jumper must be reinstalled on J3 pins 1 and 2 to return the BCC to its default setting.

2.3.4 TxD Select Header (J4)

Jumper header J4 allows the user to disconnect the transmit TxD serial data pin of the MC68332 MCU device (U5) from the RS-232C receiver/driver (U6) and use a target system receiver/driver. The BCC is shipped from the factory with the receiver/driver connected to MCU TxD (pin 52) via a cut-trace short on the bottom of the BCC PCB between J4, pins 1 and 2 (shown below). A fabricated jumper is also installed on pins 1 and 2. To disconnect the serial pin of the MCU, cut this trace and remove the jumper.



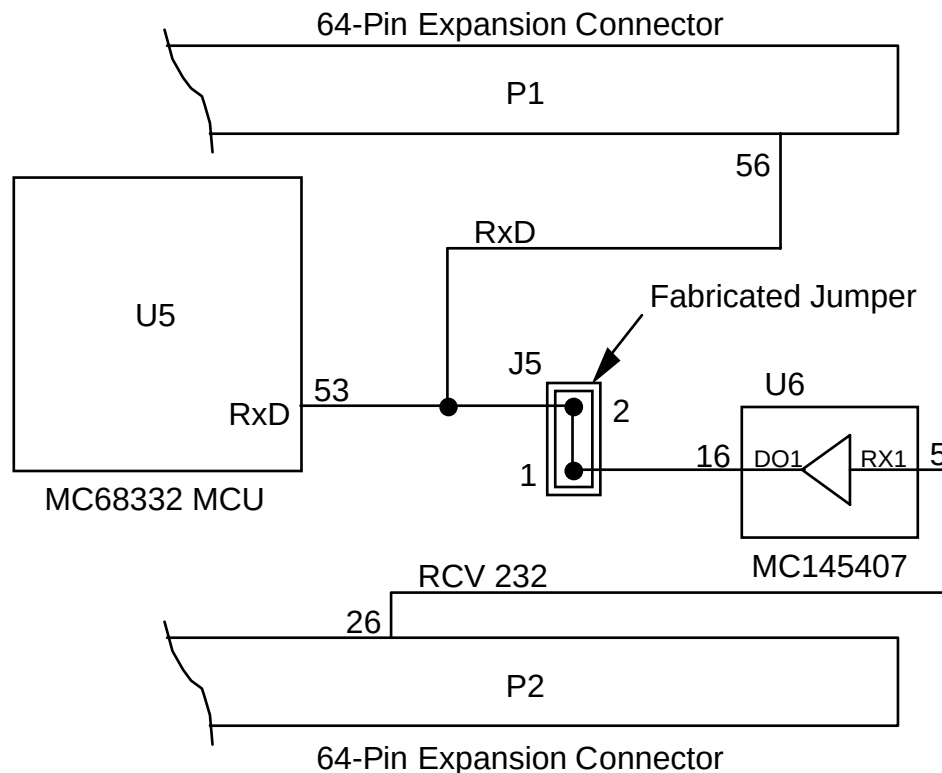
NOTE

If the cut-trace short on jumper header J4 is cut, the fabricated jumper must be reinstalled on J4 to return the BCC to its default setting.

Refer to the BCC schematic diagram for more detail on TxD signal wiring.

2.3.5 RxD Select Header (J5)

Jumper header allows the user to disconnect the receive RxD serial data pin of the MC68332 MCU device (U5) from the RS-232C receiver/driver (U6) and use a target system receiver/driver. The BCC is shipped from the factory with receiver/driver connected to MCU RxD via a cut-trace short on the bottom of the BCC PCB between J5, pins 1 and 2 (shown below). A fabricated jumper is also installed on pins 1 and 2. To disconnect the RxD pin of the MCU, cut this trace and remove the jumper.



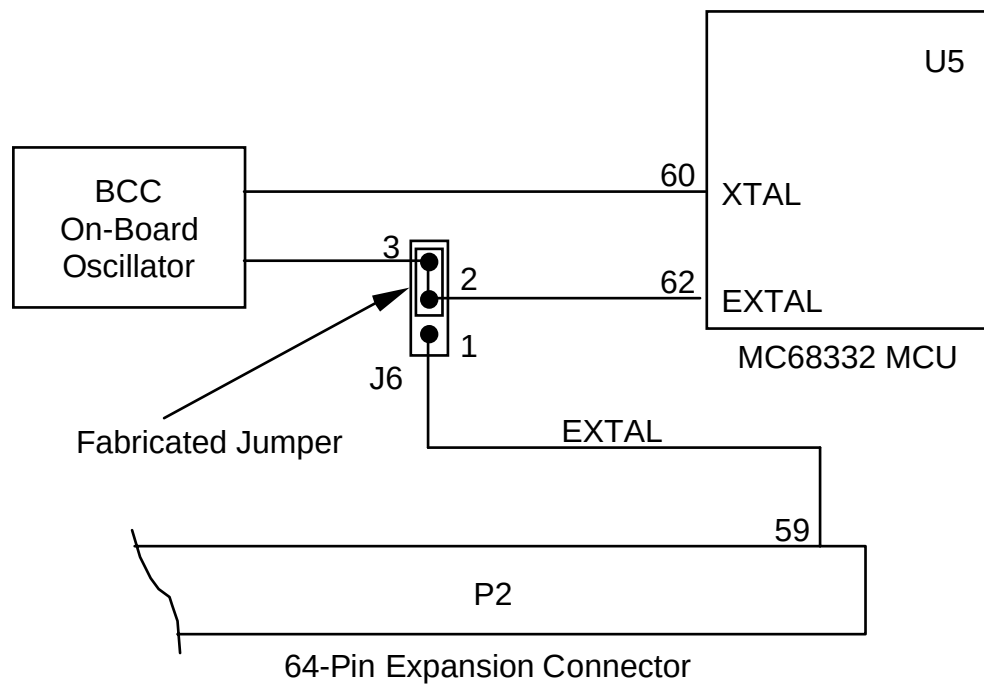
NOTE

If the cut-trace short on jumper header J5 is cut, the fabricated jumper must be reinstalled on J5 to return the BCC to its default setting.

Refer to the BCC schematic diagram for more detail on RxD signal wiring.

2.3.6 Clock Input Select Header (J6)

Use the three-pin jumper header J6 (shown below) to select the BCC on-board clock source or an external clock source. The BCC on-board clock source is a 32 kHz crystal, which is frequency multiplied by the MC68332 to a programmable operating frequency. The BCC is shipped with the on-board crystal selected as the clock source. J6 has a cut-trace short on the bottom of the BCC PCB between pins 2 and 3. A fabricated jumper is also supplied, but is not required when the user uses the on-board clock source. Refer to the BCC schematic diagram for more detail on EXTAL signal wiring.



An optional high frequency oscillator (0 to 16.77 MHz) may be used if MODCK (connector P2, pin 28) is pulled to a logic low level. To use the target-system, external-source CMOS clock; follow these steps:

- a. Turn off power to the BCC.
- b. Cut the printed circuit trace on the bottom of the BCC between pins 2 and 3.
- c. Move the fabricated jumper between pins 2 and 3 to pins 1 and 2.
- d. Supply an external oscillator to connector P2, pin 59 (EXTAL).
- e. Ground connector P2, pin 28 (MODCK).
- f. Apply power to the BCC, start the external oscillator, and drive connector P1, pin 57 (RESET), low.

NOTES

If the cut-trace short on jumper header J6 is cut, the fabricated jumper must be reinstalled on J6 pins 2 and 3 to return the BCC to its default setting.

Use a hybrid oscillator when driving the MCU from an external source.

Any change in the MC68332 MCU device clock speed causes a corresponding change in the SCI baud rate. The operational speed of the MCU is determined by the clock and the synthesizer control register value (SYNCR). The SCI baud rate is then set based on this system clock frequency. If changes are made to the MCU speed and the terminal baud rate is not changed appropriately, terminal communication will fail. Refer to Appendix C of the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1.

2.4 INSTALLATION INSTRUCTIONS

A user supplied power supply and RS-232C compatible terminal are required for BCC operation. An RS-232C compatible host computer, with terminal emulation package, may be connected to the BCC for S-record downloading.

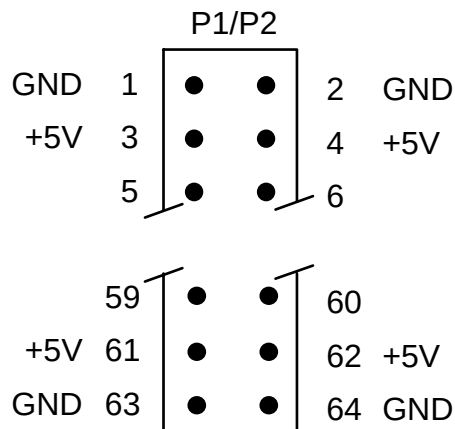
2.4.1 Power Supply - BCC Interconnection

The BCC requires +5 Vdc @ 200 mA (max.) for operation. Use 18 to 20 AWG wire to connect a user supplied power supply to the BCC. This connection is made via expansion connector P1 or P2.

There are two preferred methods for connecting the power supply to the BCC: wire-wrap and crimp-to-wire. When using the crimp-to-wire method, fabricate two wires (+5 Vdc and GND) as follows:

- Trim back 18 - 20 AWG wire approximately 0.25 inch.
- Attach a crimp-to-wire receptacle (Dupont 46227-0000) to the wire using a crimping tool.
- Place heat shrink tubing (Digi-Key W183-ND) on the crimp-to-wire receptacle and shrink using a heat source.

Connect the power supply ground fabricated wire to pin 1, 2, 63, or 64 of P1 or P2. Connect the power supply +5 Vdc fabricated wire to pin 3, 4, 61, or 62 of P1 or P2 (as shown below).



2.4.2 Terminal - BCC Interconnection

Interconnection of an RS-232C compatible terminal to the BCC is accomplished via a user supplied 9- or 25-conductor cable assembly as shown in Figures 2-2 and 2-3. If the user's terminal/host computer has a DB-9 connector refer to Figure 2-2. If the user's terminal/host computer has a DB-25 connector refer to Figure 2-3. One end of the cable assembly connects to the BCC connector J9 (shown below). The other end of the cable assembly connects to the user supplied terminal or host computer. For connector pin assignments and signal descriptions of BCC terminal port connector J9, refer to Chapter 5.

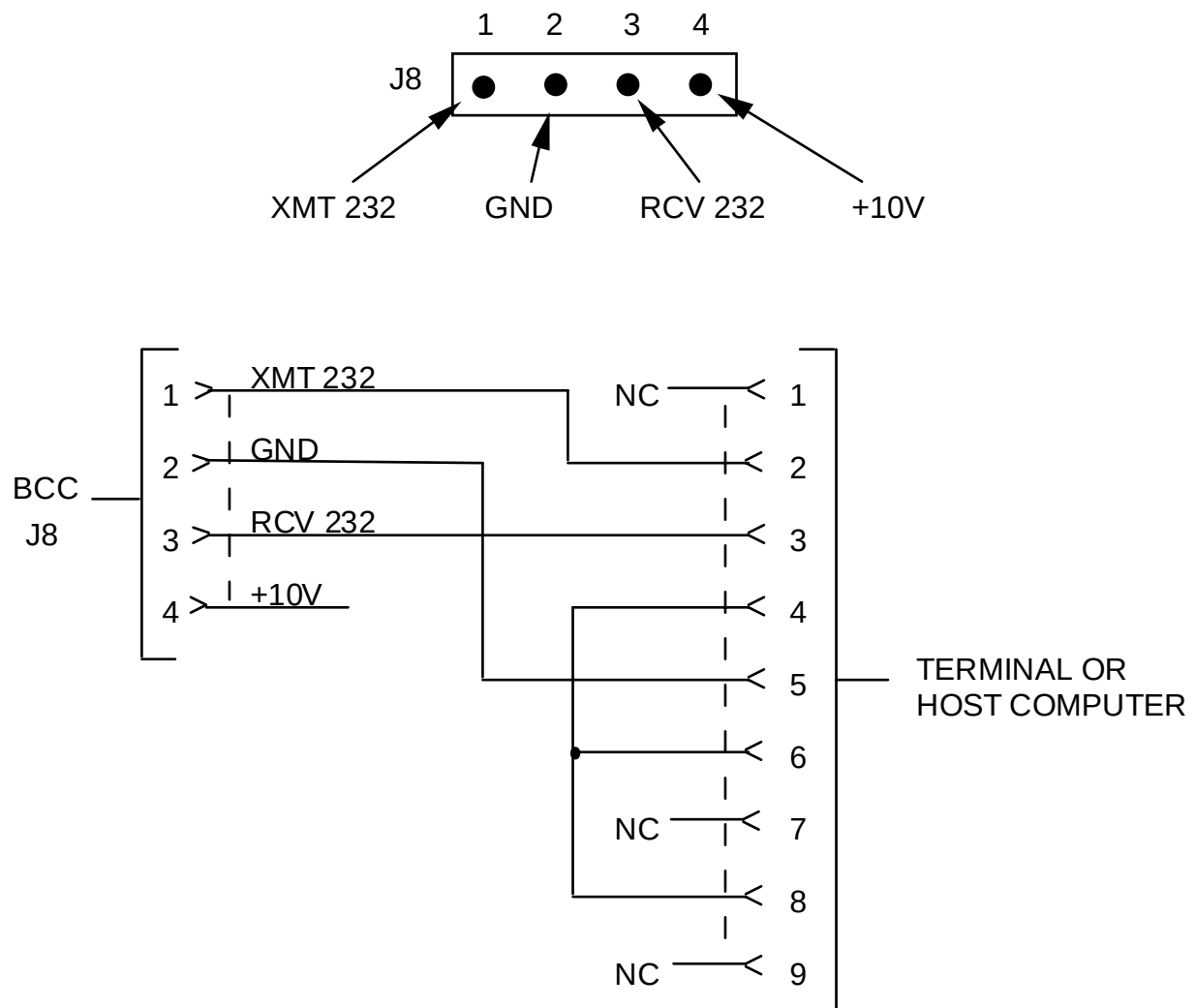
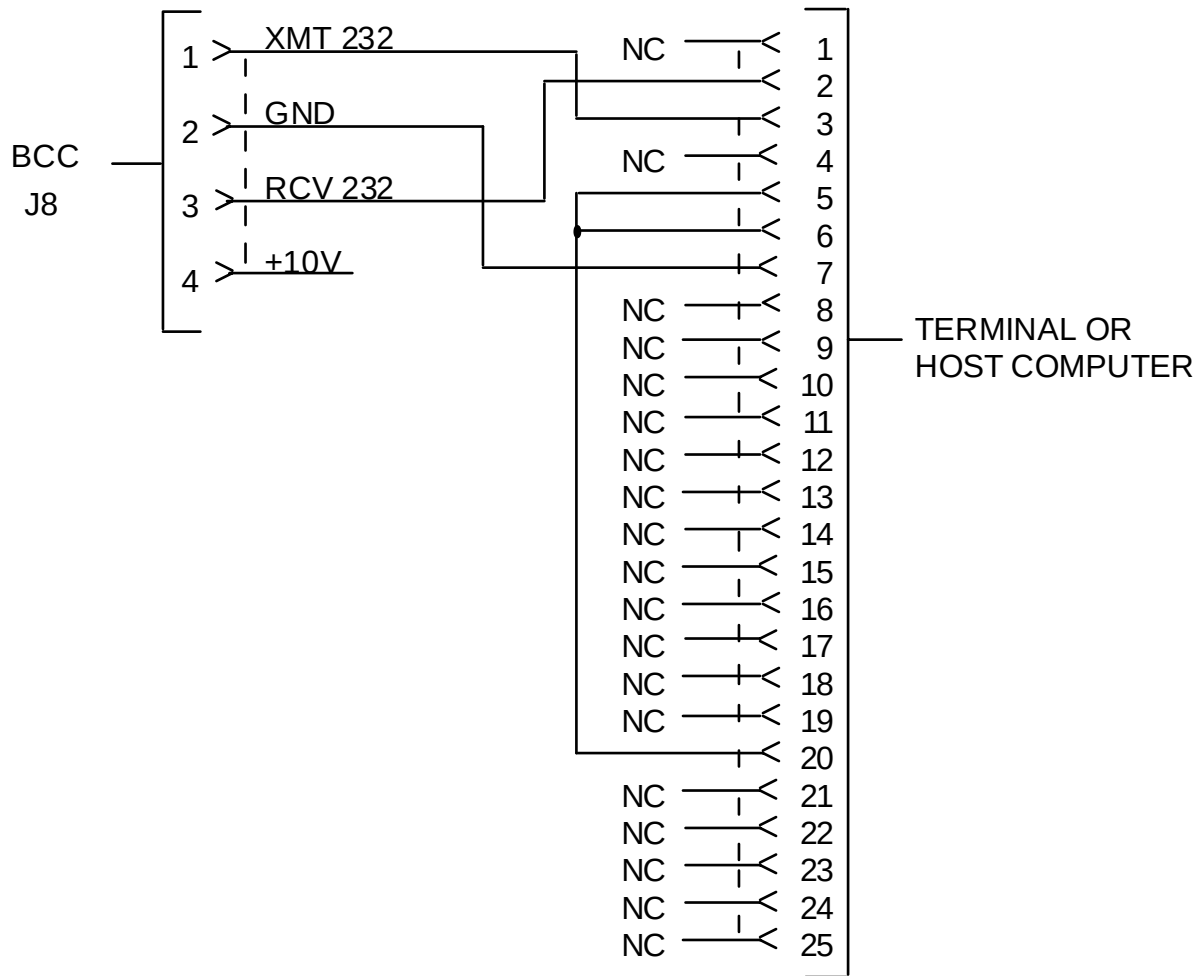
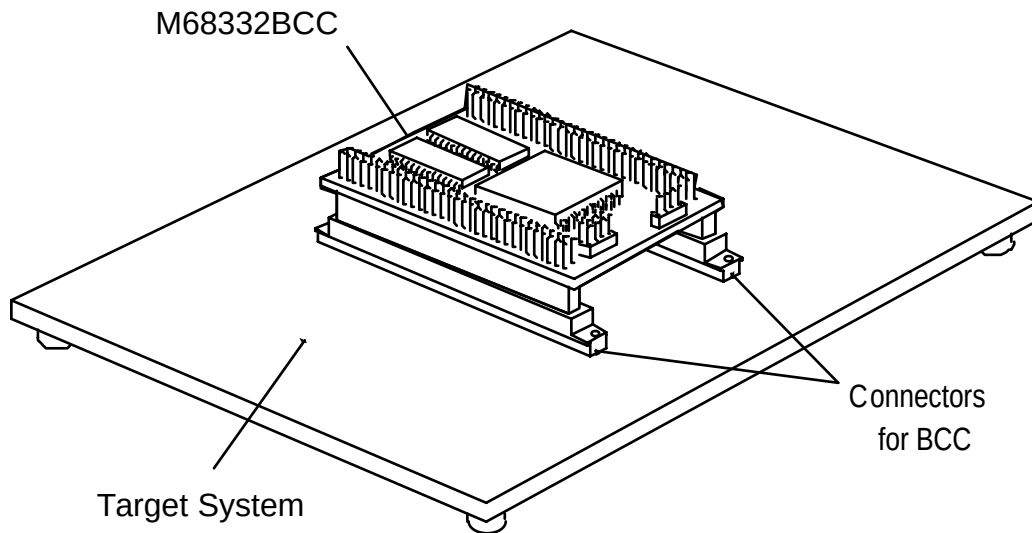


Figure 2-2. BCC to DB-9 Cable Schematic Diagram

**Figure 2-3. BCC to DB-25 Cable Schematic Diagram**

2.4.3 Target System - BCC Interconnection

For target system to BCC interconnection the BCC mounts on the target system as shown below. This configuration is used to evaluate the user's hardware design. The 64-pin expansion connectors provide access to most of the MC68332 MCU device pins. Figure 2-4 illustrates the expansion header pin assignments for the BCC. Physical dimension requirements for installing the BCC on a target system are illustrated in Figure 2-5.



Target System to BCC Interconnection

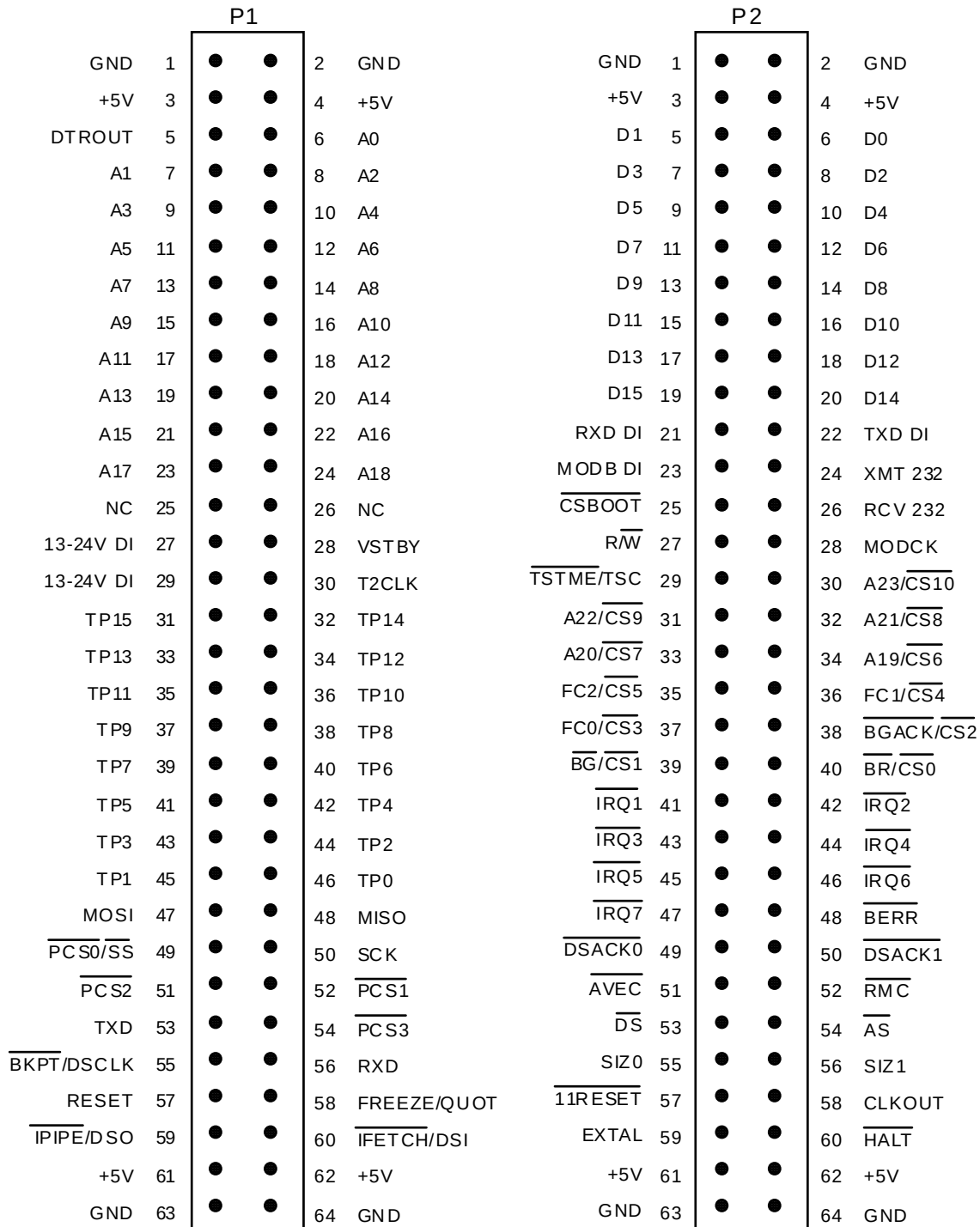


Figure 2-4. Expansion Connectors Pin Assignments

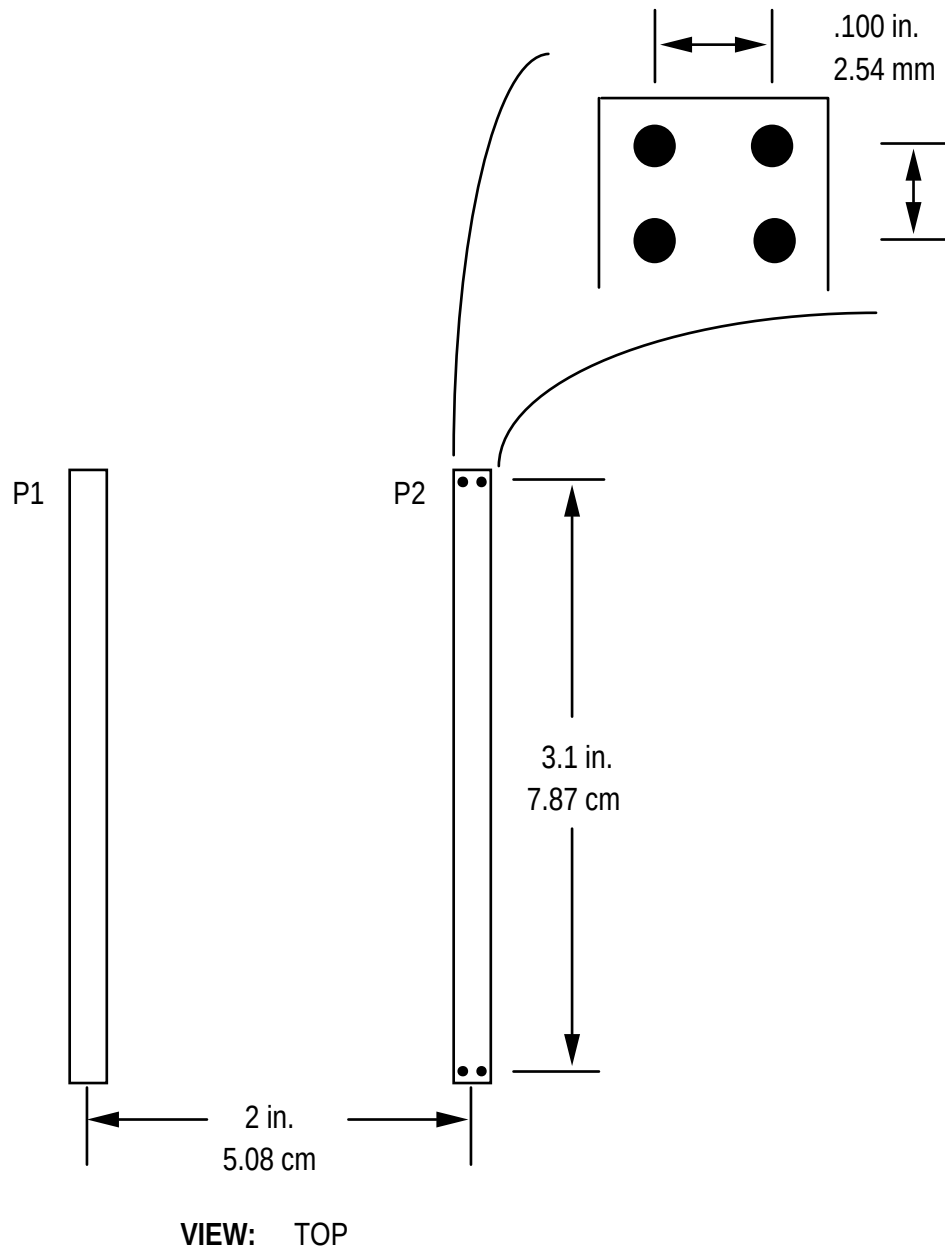


Figure 2-5. Target System Expansion Connector Installation Dimensions

CHAPTER 3

OPERATING INSTRUCTIONS

3.1 INTRODUCTION

The EPROMs on the BCC contain the M68CPU32BUG debug monitor program (hereafter referred to as CPU32Bug). CPU32Bug is a software tool for evaluating and debugging systems built around the MC68332 MCU. CPU32Bug allows loading, debugging, and executing of user programs. Various CPU32Bug routines that handle I/O, data conversion, timer, and string functions are available to user programs through system calls. For a detailed description of the CPU32Bug functions, refer to M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1.

CPU32Bug consists of:

- Memory and register display and modification commands
- Breakpoint capabilities
- System calls
- Diagnostic commands
- A single-line assembler/disassembler

There are two modes of operation in the CPU32Bug monitor; the debugger mode and the diagnostic mode. When the user is in the debugger directory the prompt **CPU32Bug>** appears, and the user has access to the debugger commands (refer to paragraph 3.4). When the user is in the diagnostic mode the prompt **CPU32Diag>** appears, and the user has access to the diagnostic commands (refer to paragraph 3.4.4). These modes are also called directories.

CPU32Bug is command-driven and performs various operations in response to user commands entered at the keyboard. CPU32Bug executes entered commands; upon completion the prompt reappears. However, if a command is entered which causes execution of user target code (i.e., GO), control may or may not return to CPU32Bug. This depends upon the user program function. Entering the help (HE) command provides a list of all possible commands and their structure.

3.2 LIMITATIONS

CPU32Bug requires some system resources to operate properly: chip selects, level 7 interrupt, software watchdog timer, periodic interrupt timer, and system exception vectors.

3.2.1 Chip Select Usage

The MC68332 MCU has chip select signals that enable peripheral devices. The BCC requires some of these chip selects for BCC operation making them unavailable to the user. Do not remove the chip selects used by the BCC, or CPU32Bug will not operate. In addition to the chip selects employed on the BCC, other chip selects are used elsewhere in the M68332EVK (refer to Tables 3-1 through 3-3).

Depending on the user's environment, any or all of the chip selects may be re-configured for an alternate function (i.e., as I/O or address lines). Chip select pins used by the BCC and EVK cannot be used in their alternate capacities.

Although a chip select (CS8 on Rev. A and CS4 on Rev. B and Rev. C BCCs) is dedicated for the ABORT switch, the pin is not used. Instead the chip select decodes the interrupt acknowledge (IACK) cycle in response to a level 7 interrupt generated by the ABORT switch. Refer the System Integration Module User's Manual (SIM32UM/AD) for more information.

When the BCC is not mounted on the M68300PFB Platform Board (PFB), these chip selects are available to the user. Also if the PFB RAM/EPROM socket pairs (U1/U3, U2/U4) and coprocessor socket U5 are not populated, the chip selects are available to the user.

Table 3-1. BCC Rev. A Chip Selection Summary

Signal	Board/Chip	Description	Memory Type
CSBOOT	BCC U2	CPU32Bug EPROM	
CS0	BCC U1	read/write enable for MSB=UPPER=EVEN	RAM
CS1	BCC U3	read/write enable for LSB=LOWER=ODD	RAM
CS2	PFB U1/U3	read enable for MSB/LSB=BOTH	RAM
CS3	PFB U1	write enable for LSB=LOWER=ODD	RAM
CS4	PFB U4	read enable for MSB=UPPER=EVEN	RAM/EPROM
CS5	PFB U2	read enable for LSB=LOWER=ODD	RAM/EPROM
CS6	PFB U5	chip enable for MC68881/882	
CS7	<unused>		
CS8	PFB	ABORT push-button autovector	
CS9	<unused>		
CS10	PFB U3	write enable for MSB=UPPER=EVEN cut/jump U3-27 from CS4 to CS10 required.	RAM

Table 3-2. BCC Rev. B Chip Selection Summary

Signal	Board/Chip	Description	Memory Type
CSBOOT	BCC U2	CPU32Bug EPROM	
CS0	BCC U1	write enable for MSB=UPPER=EVEN	RAM
CS1	BCC U3	write enable for LSB=LOWER=ODD	RAM
CS2	BCC U3/U1	read enable for MSB/LSB=BOTH	RAM
CS3	<unused>		
CS4	PFB	ABORT push-button autovector	
CS5	PFB U5	chip enable for MC68881/882. cut/-jump U5-J3 from CS2 to CS5 required.	
CS6	PFB U2	read enable for LSB=LOWER=ODD	RAM/EPROM
CS7	PFB U4	read enable for MSB=UPPER=EVEN	RAM/EPROM
CS8	PFB U1/U3	read enable for MSB/LSB=BOTH	RAM
CS9	PFB U1	write enable for LSB=LOWER=ODD	RAM
CS10	PFB U3	write enable for MSB=UPPER=EVEN	RAM

Table 3-3. BCC Rev. C Chip Selection Summary

Signal	Board/Chip	Description	Memory Type
CSBOOT	BCC U3	CPU32Bug EPROM for MSB=UPPER=EVEN	
CSBOOT	BCC U4	CPU32Bug EPROM for LSB=LOWER=ODD	
CS0	BCC U1	write enable for MSB=UPPER=EVEN	RAM
CS1	BCC U2	write enable for LSB=LOWER=ODD	RAM
CS2	BCC U3/U1	read enable for MSB/LSB=BOTH	RAM
CS3	<unused>		
CS4	PFB	ABORT push-button autovector	
CS5	PFB U5	chip enable for MC68881/882. cut/-jump U5-J3 from CS2 to CS5 required.	
CS6	PFB U2	read enable for LSB=LOWER=ODD	RAM/EPROM
CS7	PFB U4	read enable for MSB=UPPER=EVEN	RAM/EPROM
CS8	PFB U1/U3	read enable for MSB/LSB=BOTH	RAM
CS9	PFB U1	write enable for LSB=LOWER=ODD	RAM
CS10	PFB U3	write enable for MSB=UPPER=EVEN	RAM

3.2.2 Other MCU Resources Used by CPU32Bug

Avoid writing the value zero to bit 7 of the port F pin assignment register (PFPAR); such a value disables the ABORT switch.

The software watchdog timer is disabled via a write-once register (SYPCR) during power-up or reset, so the software watchdog timer cannot be used or re-enabled by the user unless the user modifies the SYPCR_OR and SYPCR_AND parameters. Modification of the SYPCR_OR and SYPCR_AND parameters is detailed in Appendix C of the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1.

The monitor uses the system exception vectors, so they are unavailable to the BCC user. The monitor debug exception vectors are listed in Table 3-4. The associated debugger facilities (breakpoints, trace mode, etc.) will not operate if the vector offsets in the target program vector table are changed.

Table 3-4. CPU32Bug Exception Vectors

Vector Number	Offset	Exception	CPU32Bug Commands
4	\$10	Illegal	Instruction breakpoints (Used by GO, GN, GT)
9	\$24	Trace	T, TC, TT
31	\$7C	Level 7 interrupt	ABORT switch
47	\$BC	TRAP #15	System calls (see Chapter 5 of the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1)
66	\$108	User Defined	Timer Trap #15 Calls (\$4X)

Any change in the MC68332 MCU device clock speed causes a corresponding change in the SCI baud rate. The operational speed of the MCU is determined by the clock and the synthesizer control register value (SYNCR) or by an external clock signal applied to the EXTAL pin of the MCU. The SCI baud rate is then set based on this system clock frequency. If changes are made to the MCU system clock frequency, changes must be made to the customization parameter area (FCRYSTAL or FEXTAL) so the correct baud rate can be calculated for SCI communications by CPU32Bug. See the M68CPU32BUG Debug Monitor User's Manual (M68CPU32BUG/AD1), Appendix C for details.

Additionally, CPU32Bug writes a one (1) to the module mapping (MM) bit of the module control register (MCR). This configures the register block to start at address \$FFF000. As the MM bit is a write-once bit, the user cannot clear it to move the register block to low memory (\$7FF000). The user can move the register block by modifying the MCR_AND parameter detailed in Appendix C of the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1.

3.3 OPERATING PROCEDURE

A Power On Reset (POR) occurs when power is applied to the BCC. This POR condition resets the MCU and user I/O port circuitry. After a POR occurs, processing control passes to the monitor program. All MC68332 registers are set to their reset state during monitor power-up.

The input serial format for the BCC terminal I/O port must be configured for 8 data bits, 1 stop bit, no parity, and 9600 baud.

The terminal then displays this message:

```
CPU32Bug Debugger/Diagnostics - Version X.XX  
  (C) Copyright 1989, 1990 by Motorola Inc.  
CPU32Bug>
```

where:

X.XX is the software revision level

After initialization or return of control to the monitor, the terminal displays the prompt "CPU32Bug>" and waits for a response. If an incorrect response is entered, the terminal displays "Invalid command" followed by the prompt "CPU32Bug>".

CPU32Bug waits for a command line input from the user terminal. When a proper command is entered, the operation continues in one of two basic modes. If the command causes execution of a user program, the monitor may or may not be reentered, depending upon the desire of the user. For the alternate case, the command is executed under the control of the monitor, and the system returns to a waiting condition after the command is completed. During command execution, additional user input may be required, depending on the command function.

The user can use any of the commands supported by the monitor. A standard input routine controls the BCC operation while the user types a command line. Command processing begins only after the command line has been terminated by pressing the keyboard carriage return <CR> key.

3.4 MONITOR DESCRIPTION

CPU32Bug performs various operations in response to user commands entered at the keyboard. When the debugger prompt **CPU32Bug>** appears on the terminal screen, the debugger is ready to accept commands.

As the command line is entered it is stored in an internal buffer. Execution begins only after the carriage return is entered. This lets the user correct entry errors using the control characters described in the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1.

After the debugger executes a command it returns with the **CPU32Bug>** prompt. However, if the entered command causes execution of user target code, (i.e., **GO**), then control may or may not return to the debugger. This depends on the user program function. For example, if a breakpoint is specified, control returns to the debugger when the breakpoint is encountered during user program execution. The user program also returns control to the debugger by means of the TRAP #15 system call function, **.RETURN**.

Included as part of the CPU32Bug firmware is a single-line assembler/disassembler function. The assembler is an interactive assembler/editor in which source programs are not saved. Each source line is translated into MC68332 MCU machine language code and stored line-by-line into memory as it is entered. In order to display an instruction, the machine code is disassembled and the instruction mnemonic and operands are displayed. All valid MC68332 MCU instructions are supported.

The CPU32Bug assembler is effectively a subset of the M68000 Family Structured Assembler (M68MASM). It has some limitations as compared with the M68MASM assembler, such as not allowing line numbers and labels; however, it is a useful tool for creating, modifying, and debugging MC68332 MCU code.

3.4.1 Memory and Register Display and Modification Commands

Various commands are available to the user for displaying and modifying memory. For more information, refer to Chapter 3 of the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1. The memory display and modification commands are:

- **BF** (block of memory fill) fills the specified range of memory with a data pattern.
- **BM** (block of memory move) copies the contents of the memory addresses defined by <RANGE> to another place in memory, beginning at <ADDR>.
- **BS** (block of memory search) searches the specified range of memory for a match with a user-entered data pattern.
- **BV** (block of memory verify) compares the specified range of memory against a data pattern.
- **MD** (memory display) displays the contents of multiple memory locations.
- **MM** (memory modify) examines and changes memory locations.
- **MS** (memory set) writes data to memory starting at a specified address.
- **RD** (register display) displays the contents of the MCU registers.
- **RM** (register modify) examines and changes register contents.
- **RS** (register set) writes data to a specified register.

3.4.2 Breakpoint Capabilities

A breakpoint lets the user set a target code instruction address stopping point for debugging purposes. Target code execution halts when a breakpoint is encountered. For more information on breakpoints, refer to Chapter 3 of the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1. The breakpoint commands are:

- **BR/NOBR** (breakpoint insert/delete) allows the user to set/remove a target code instruction address as a breakpoint address for debugging purposes.
- **GD** (go direct) starts target code execution and ignores breakpoints.
- **GN** (go to temporary breakpoint) sets a temporary breakpoint at the address of the next instruction, that is, the one following the current instruction.
- **GT** (go to temporary breakpoint) sets a temporary breakpoint at the current instruction and starts target code execution.
- **TT** (trace to temporary breakpoint) sets a temporary breakpoint at a specified address and traces until encountering a breakpoint.

3.4.3 System Calls

The CPU32Bug TRAP #15 handler allows system calls from user programs. A system call accesses selected functional routines contained in CPU32Bug, including input and output routines. TRAP #15 also transfers control to CPU32Bug at the end of a user program. For more information on system calls, refer to Chapter 5 of the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1. System calls include:

- **.INCHR** (input character) reads a character from the default input port.
- **.INSTAT** (input serial port status) checks for characters in the default input port buffer.
- **.INLN** (input line (pointer/pointer format)) reads a line from the default input port.
- **.READSTR** (input string (pointer/count format)) reads a string of characters from the default input port into a buffer.
- **.READLN** (input line (pointer/count format)) reads a string of characters from the default input port.
- **.CHKBRK** (check for break) returns zero (0) status in condition code register if break status is detected at the default input port.
- **.OUTCHR** (output character) outputs a character to the default output port.
- **.OUTSTR** (output string in pointer/pointer format) outputs a string of characters to the default output port.
- **.OUTLN** (output line in pointer/pointer format) outputs a character strings followed by a carriage return (<CR>) and a line feed (<LF>) sequence.
- **.WRITE** (output string in pointer/count format) formats character strings with a count byte and outputs the string to the default output port. After formatting, the count byte is the first byte in the string.
- **.WRITELN** (output line in pointer/count format) formats character strings with a count byte and outputs the string to the default output port. After formatting, the count byte is the first byte in the string.
- **.PCRLF** (output carriage return and line feed) sends a <CR> and a <LF> sequence to the default output port.
- **.ERASLN** (erase line) erases the line at the present cursor position.
- **.WRITD** (output string with data in pointer/count format) uses the monitor I/O routine which outputs a user string containing embedded variable fields. The user passes the starting address of the string and the data stack address containing the data which is inserted into the string. The output goes to the default output port.

- **.WRITDLN** (output line with data in pointer/count format) uses the monitor I/O routine which outputs a user string containing embedded variable fields. The user passes the starting address of the string and the data stack address containing the data which is inserted into the string. The output goes to the default output port.
- **.SNDBRK** (send break) sends a break to the default output port.
- **.TM_INI** (timer initialization) initializes the MC68331 MCU device periodic interrupt timer.
- **.TM_STR0** (start timer at T=0) resets the timer to zero and starts it.
- **.TM_RD** (read timer) reads the timer count.
- **.DELAY** (timer delay) generates timing delays.
- **.RETURN** (return to CPU32Bug) returns control to CPU32Bug from the target program.
- **.BINDEC** (convert binary to Binary Coded Decimal) calculates the BCD equivalent of a specified binary number.
- **.CHANGEV** (parse value) parses value in user specified buffer.
- **.STRCMP** (compare two strings in pointer/count format) compares equality and returns a Boolean flag to the caller.
- **.MULU32** (multiply two 32-bit unsigned integers) multiplies two 32-bit unsigned integers and returns the product on the stack as a 32-bit unsigned integer.
- **.DIVU32** (divide two 32-bit unsigned integers) divides two 32-bit unsigned integers and returns the quotient on the stack as a 32-bit unsigned integer.

3.4.4 Diagnostic Monitor

The diagnostic monitor is a series of self-tests for the MC68332 MCU device. The diagnostic monitor is programmed into the BCC EPROM. For more information on the diagnostic monitor, refer to Chapter 6 of the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1. The diagnostic monitor commands are:

- **HE** (help) command displays a menu of the top level directory.
- **ST** (self test) command executes self-test diagnostics.
- **SD** (switch directories) command toggles between the CPU32Bug directory and the CPU32Diag directory.
- **LE** (loop-on-error) endlessly repeats a test at the point where an error is detected.
- **SE** (Stop-On-Error) halts a test at the point where an error is detected.
- **LC** (loop-continue) endlessly repeats a test or series of tests.
- **NV** (non-verbose) suppresses all error messages except PASSED or FAILED.
- **DE** (display error counters) displays the results of a particular test.
- **ZE** (clear error counters) resets all error counters to zero.
- **DP** (display pass count) is the number of passes in loop-continue mode. Under this command the count is displayed with other information at the conclusion of each pass.
- **ZP** (zero pass count) resets the pass counter to zero.

Available utilities are:

- **WL** - Write Loop
- **RL** - Read Loop
- **WR** - Read/Write Loop

CPU tests are a series of diagnostics provided to test the CPU portion of the MC68332 MPU:

- **CPU A** - Register Test
- **CPU B** - Instruction Test
- **CPU C** - Address Mode Test
- **CPU D** - Exception Processing Test

Memory tests are a series of diagnostics that verify random access memory (read/write) that may reside on the BCC.

- **MT A** - Set Function Code
- **MT B** - Set Start Address
- **MT C** - Set Stop Address
- **MT D** - Set Bus Data Width
- **MT E** - March Address Test
- **MT F** - Walk a Bit Test
- **MT G** - Refresh Test
- **MT H** - Random Byte Test
- **MT I** - Program Test
- **MT J** - TAS Test

Bus error test (**BERR**) tests for internal bus access time-out and internal to external bus access time-out error conditions, including:

- Bus errors when accessing the BCC RAM.
- Bus errors when reading the BCC EPROM.
- Bus errors when accessing the PFB optional memory.
- Internal bus access time-outs when reading and writing from an undefined function code/memory location internal to the MCU.
- Internal to external bus access time-outs reading or writing to an undefined function code/memory location external to the MCU.

3.5 ASSEMBLING/DISASSEMBLING PROCEDURE

The assembler/disassembler is an interactive, one-line assembler/editor in which the source program is not saved. Each source line is converted into machine language code and is stored in memory on a line-by-line basis at the time of entry. In order to display an instruction, the machine code is disassembled and the instruction mnemonic and operands are displayed. All valid opcodes are converted to assembly language mnemonic. All invalid opcodes return a Declare Constant Word (DC.W) conversion.

The memory modify (**mm ;di**) command lets the user create, modify, and debug MC68332 MCU code. Assembler input must have exactly one space between the mnemonic and the operand. There must be no space inside the operand field. Assembler input must be terminated by a carriage return. No comments are allowed after the instruction input and no line labels are permitted.

After each new assembler input line, the new line is disassembled for the user before stepping to the new instruction. The new line may assemble to a different number of bytes than the previous one.

For Branch if Higher or Same (BHS)/Branch if Carry Clear (BCC) mnemonics, disassembly displays the BCC mnemonic. For Branch if Lower (BLO)/Branch if Carry Set (BCS) mnemonics, disassembly displays the BCS mnemonic.

Branch address offsets are automatically calculated by the assembler, so the user should input the destination address rather than an offset value.

The assembler is terminated by entering a period (.) followed by a carriage return as the only entry on the command input line. Entering a carriage return alone on an input line steps to the next instruction.

The following pages describe how to operate the assembler/disassembler by creating a typical program loop, and debugging the program using CPU32Bug monitor commands. A typical program loop is first assembled. Routine examples then illustrate how to set a breakpoint, proceed from a breakpoint, display and modify registers, and initiate user program execution.

Enter the periodic interrupt timer (PIT) time-out program starting at address \$5000:

<u>EXAMPLE PROGRAM</u>	<u>PROGRAM DESCRIPTION</u>
CPU32Bug>MM 5000;DI<CR>	<i>Memory modify at location \$5000 with disassembly option.</i>
5000 MOVE.L #\$501C,\$78<CR>	<i>Set-up level six vector table.</i>
5008 MOVE.L #\$061E0120,\$FFFA22<CR>	<i>Initialize PIT.</i>
5012 LPSTOP #\$2500<CR>	<i>Execute LPSTOP Instruction.</i>
5018 BRA.W \$5012<CR>	<i>Loop</i>
501C MOVEA.W #\$5100,A0<CR>	<i>Beginning of message.</i>
5020 MOVEA.W #\$510E,A1<CR>	<i>End of message.</i>
5024 BTST.B #\$0,\$FFFC0C<CR>	<i>Check for SCI not busy.</i>
502C BEQ.B \$5024<CR>	<i>Branch until free.</i>
502E MOVE.B (A0)+,\$FFFC0F<CR>	<i>Send message byte.</i>
5034 CMPA.W A0,A1<CR>	<i>Check for end of message.</i>
5036 BNE.W \$5024<CR>	<i>Branch until done.</i>
503A RTE<CR>	<i>Return from print routine.</i>

Enter the ASCII code for the output message, PIT TIME-OUT. Each time this message appears when running the program, indicates the program has completed a loop. Enter the following ASCII code at memory location \$5100:

CPU32Bug>MS 5100 'PIT TIME-OUT'OD0A<CR>	<i>Memory modify at location \$5100.</i>
---	--

After entering the PIT time-out program display the instructions at location \$5000

**EXAMPLE
PROGRAM**

**PROGRAM
DESCRIPTION**

CPU32Bug>**MD 5000;DI<CR>**

*Display memory at location \$5000 with
disassembly option.*

5000	21FC0000 501C0078	MOVE.L	#\$501C, (\$78).W
5008	23FC061E 012000FF		
	FA22	MOVE.L	#\$061E0120, (\$FFFA22).L
5012	F80001C0 2500	LPSTOP.W	#\$2500
5018	6000FFF8	BRA.W	\$5012
501C	307C5100	MOVEA.W	#\$5100, A0
5020	327C510E	MOVEA.W	#\$510E, A1
5024	08390000 00FFFC0C	BTST.B	#\$0, (\$FFFC0C).L
502C	67F6	BEQ.B	\$5024

CPU32Bug>**<CR>**

Display next eight instructions.

502E	13D800FF FC0F	MOVE.B	(A0)+, (FFFC0F).L.
5034	B2C8	CMPA.W	A0, A1
5036	6600FFEC	BNE.W	\$5024
503A	4E73	RTE	
503C	0000FFFF	ORI.B	#\$FF, D0
5040	0000FFFF	ORI.B	#\$FF, D0
5044	0000FFFF	ORI.B	#\$FF, D0
5048	0000FFFF	ORI.B	#\$FF, D0

The message displayed on the terminal

CPU32Bug>**MD 5100<CR>**

00005100 5049 5420 5449 4D45 2D4F 5554 0D0A FFFF PIT TIME-OUT....

The following routines are performed on the preceding program loop:

<u>TERMINAL</u>	<u>ROUTINE DESCRIPTION</u>
CPU32Bug>MD 5000;DI<CR>	<i>Display memory at address 5000</i>
00005000 21FC0000 501C0078 MOVE.L #\$501C, (\$78).W	
00005008 23FC061E 012000FF FA22 MOVE.L #\$061E0120, (FFFA22)	
00005012 F80001C0 2500 LPSTOP.W #\$2500	
00005018 6000FFF8 BRA.W \$5012	
0000501C 307C5100 MOVEA.W #\$5100, A0	
00005020 327C510E MOVEA.W #\$510E, A1	
00005024 08390000 00FFFC0C BTST.B #\$0, (\$FFFC0C).L	
0000502C 67F6 BEQ.B \$5024	
CPU32Bug>MM 500C<CR>	<i>Modify memory at location 500C.</i>
0000500C 0120? 00FF.	<i>Change PIT time-out speed.</i>
CPU32Bug>g 5000<CR>	<i>Go to address 5000 and begin execution.</i>
Effective address: 00005000	
PIT TIME-OUT	<i>Periodic interrupt timer time-out message.</i>
PIT TIME-OUT	
PIT TIME-OUT	
:	
:	
Press the ABORT switch on the PFB to terminate the loop program.	
Exception: ABORT	
PC =00005018 SR =2500=TR:OFF_S_5_..... VBR =00000000	
SFC =5=SD DFC =5=SD USP =0000FC00 SSP* =00010000	
D0 =00000000 D1 =00000000 D2 =00000000 D3 =00000000	
D4 =00000000 D5 =00000000 D6 =00000000 D7 =00000000	
A0 =0000510E A1 =0000510E A2 =00000000 A3 =00000000	
A4 =00000000 A5 =00000000 A6 =00000000 A7 =00010000	
00005018 6000FFF8 BRA.W.W \$5012	
CPU32Bug>T 1<CR>	<i>Trace one instruction.</i>
PC =00005018 SR =2500=TR:OFF_S_5_..... VBR =00000000	
SFC =5=SD DFC =5=SD USP =0000FC00 SSP* =00010000	
D0 =00000000 D1 =00000000 D2 =00000000 D3 =00000000	
D4 =00000000 D5 =00000000 D6 =00000000 D7 =00000000	
A0 =0000510E A1 =0000510E A2 =00000000 A3 =00000000	
A4 =00000000 A5 =00000000 A6 =00000000 A7 =00010000	
00005012 F80001C0 2500 LPSTOP.W #\$2500	
CPU32Bug>BR 5034<CR>	<i>Set breakpoint at 5034.</i>
BREAKPOINTS	
00005034	
CPU32Bug>g 5000<CR>	<i>Go to address 5000 and begin execution.</i>
Effective address: 00005018	
At Breakpoint	
PC =00005034 SR =2600=TR:OFF_S_6_..... VBR =00000000	
SFC =5=SD DFC =5=SD USP =0000FC00 SSP* =0000FFF8	
D0 =00000000 D1 =00000000 D2 =00000000 D3 =00000000	
D4 =00000000 D5 =00000000 D6 =00000000 D7 =00000000	
A0 =00005101 A1 =0000510E A2 =00000000 A3 =00000000	
A4 =00000000 A5 =00000000 A6 =00000000 A7 =0000FFF8	
00005034 B2C8 CMPA.W A0, A1	

3.6 DOWNLOADING PROCEDURES

Downloading transfers information from a host computer to the BCC, via the load (**LO**) command. The procedure described below lets the user download with an IBM personal computer (PC) or Apple Macintosh host computer.

The **LO** command moves data in S-record format (see Appendix A) from an external host computer to the EVK user pseudo ROM.

Subsections 3.6.1 through 3.6.4 list instructions for downloading to the EVK from an Apple Macintosh with MacTerminal or Red Ryder, or from an IBM-PC with Kermit or PROCOMM.

3.6.1 Apple Macintosh (with MacTerminal) to BCC

The MacTerminal downloading program serves as a terminal emulator for the Apple Macintosh computer. To download a Motorola S-record file from the Apple Macintosh computer to the BCC:

- a. Select the following menu Terminal Settings:

Terminal:	VT100
Mode:	ANSI
Cursor Shape:	Underline
Line Width:	80 Columns
Select:	On Line
	Auto Repeat
Click on:	OK

- b. Select the following menu Compatibility Settings:

Baud rate:	9600
Bits per Character:	8 Bits
Parity:	None
Handshake:	XOn/XOff
Connection:	Another Computer
Connection Port:	Modem
Click on:	OK

- c. Select the following menu File Transfer Settings:

Settings for Pasting or Sending Text:	Word Wrap Outgoing Text
File Transfer Protocol:	Text
Settings for Saving Lines Off Top:	Retain Line Breaks
Click on:	OK

- d. Apply power to the BCC.
- e. Press Apple Macintosh computer keyboard carriage return (<CR>) key to display applicable BCC monitor prompt.
- f. Apple Macintosh computer displays the CPU32Bug> prompt.
- g. Enter BCC monitor download command as follows:
CPU32Bug>LO<CR>
- h. Operate pull-down File menu, and select (choose): Send File ...
- i. Use dialog box and select applicable S-record object file.
Click on: Send
Motorola S-record file is now transferred to the BCC.

NOTE

S-record file will not be displayed during the file transfer to the BCC.

The underline cursor flashes and the beeper sounds when the S-record has finished downloading. Press the carriage return twice to return to the CPU32Bug prompt:

```
<CR>  
<CR>  
CPU32Bug>
```

3.6.2 Apple Macintosh (with White Knight) to BCC

The White Knight downloading program serves as a terminal emulator for the Apple Macintosh computer. To download a Motorola S-record file from the Apple Macintosh computer to the BCC:

- a. Execute White Knight program.
- b. Set up computer program to match BCC baud rate (typically) as follows:
9600 baud, no parity, 8-bits, 1-stop bit, full duplex
- c. Apply power to BCC.
- d. Press Apple Macintosh computer keyboard carriage return (<CR>) key to display applicable BCC monitor prompt.
- e. Enter BCC monitor download command as follows:
CPU32Bug>LO<CR>
- f. Operate pull-down File menu, and select (choose):
Send File - ASCII...
- g. Use dialog box and select applicable S-record object file.
Click on: Send
Motorola S-record file is now transferred to the BCC.

NOTE

S-record file will not be displayed during the file transfer to the BCC.

The underline cursor flashes and the beeper sounds when the S-record has finished downloading. Press the carriage return twice to return to the CPU32Bug prompt:

```
<CR>
<CR>
CPU32Bug>
```

3.6.3 IBM-PC (with KERMIT) to BCC

Before performing any IBM-PC operation, ensure that both IBM-PC and BCC baud rates are 9600, and that the IBM-PC asynchronous port is configured for terminal mode of operation. If the asynchronous port is hard wired for host mode of operation and cannot be re-configured for a terminal mode of operation, the use a null modem (cross-coupled transmit (TxD), and receive (RxD), and associated handshake lines) is required.

NOTE

IBM-PC to BCC connection requires one serial communication cable assembly. This cable is connected to the BCC terminal I/O port connector J9 for downloading operations.

To perform IBM-PC to BCC downloading procedure:

EXAMPLE	DESCRIPTION
C> KERMIT <CR> IBM-PC Kermit-MS VX.XX Type ? for help	<i>IBM-PC prompt. Enter Kermit program.</i>
Kermit-MS> SET BAUD 9600 <CR> Kermit-MS> CONNECT <CR>	<i>Set IBM-PC baud rate. Connect IBM-PC to BCC.</i>
[Connecting to host, type Control-] C to return to PC]	
<CR> CPU32Bug> LO <CR> (CTRL)]C Kermit-MS> PUSH <CR>	<i>BCC download command (via terminal port) entered.</i>
The IBM Personal Computer DOS Version X.XX (C)Copyright IBM Corp. 1981, 1982, 1983	
C> TYPE (File Name) > COM1 <CR>	<i>Motorola S-record file name.</i>
C> EXIT <CR>	<i>S-record downloading completed.</i>
Kermit-MS> CONNECT <CR>	<i>Return to BCC monitor program.</i>

The underline cursor flashes and the beeper sounds when the S-record has finished downloading. Press the carriage return twice to return to the CPU32Bug prompt:

<CR>

<CR>

CPU32Bug>

CPU32Bug>(CTRL)]C

KERMIT-MS>EXIT<CR>

Exit Kermit program.

3.6.4 IBM-PC (with PROCOMM) to BCC

To perform the IBM-PC to BCC downloading procedure with PROCOMM:

- a. Execute the PROCOMM.EXE program.
- b. Setup PROCOMM to match BCC baud rate and protocol (type (Alt)P, then the number 11) as follows:
 9600 baud, no parity, 8 bits, 1 stop bit, full duplex
- c. Setup ASCII transfer parameters (type (Alt)S, then the number 6) as follows:
 Echo Local - No
 Expand Blank Lines - Yes
 Pace Character - 0
 Character pacing - 15 (milliseconds)
 Line Pacing - 10
 CR Translation - None
 LF Translation - None
 Save above settings to disk for future use.
- d. Apply power to BCC.
- e. Press IBM-PC keyboard carriage return (<CR>) key to display applicable BCC monitor prompt.
- f. Enter BCC monitor download command as follows:
 CPU32Bug>LO<CR>
- g. Instruct PROCOMM to send the S-record file by pressing the Pg Up key on the PC, then follow PROCOMM instructions on the display screen to select the S-record file using an ASCII protocol.

Motorola S-record file is transferred to the BCC when the beeper sounds and the underline cursor flashes. Press the carriage return twice to return to the CPU32Bug prompt:

```
<CR>
<CR>
CPU32Bug>
```

CHAPTER 4

FUNCTIONAL DESCRIPTION

4.1 INTRODUCTION

This chapter provides a functional description of the BCC. This description is supported by a block diagram (Figure 4-1) and a memory map diagram (Figure 4-2). Refer to Chapter 5 for the BCC schematic diagram.

4.2 BCC DESCRIPTION

The MC68332 Microcontroller Unit (MCU) resident on the BCC provides resources for designing, debugging, and evaluating MC68332 MCU based target systems and simplifies user evaluation of prototype hardware/software products.

Figure 4-1 is a block diagram of these BCC circuits:

- MCU
- User memory
- Terminal and host computer I/O port
- Background mode interface port

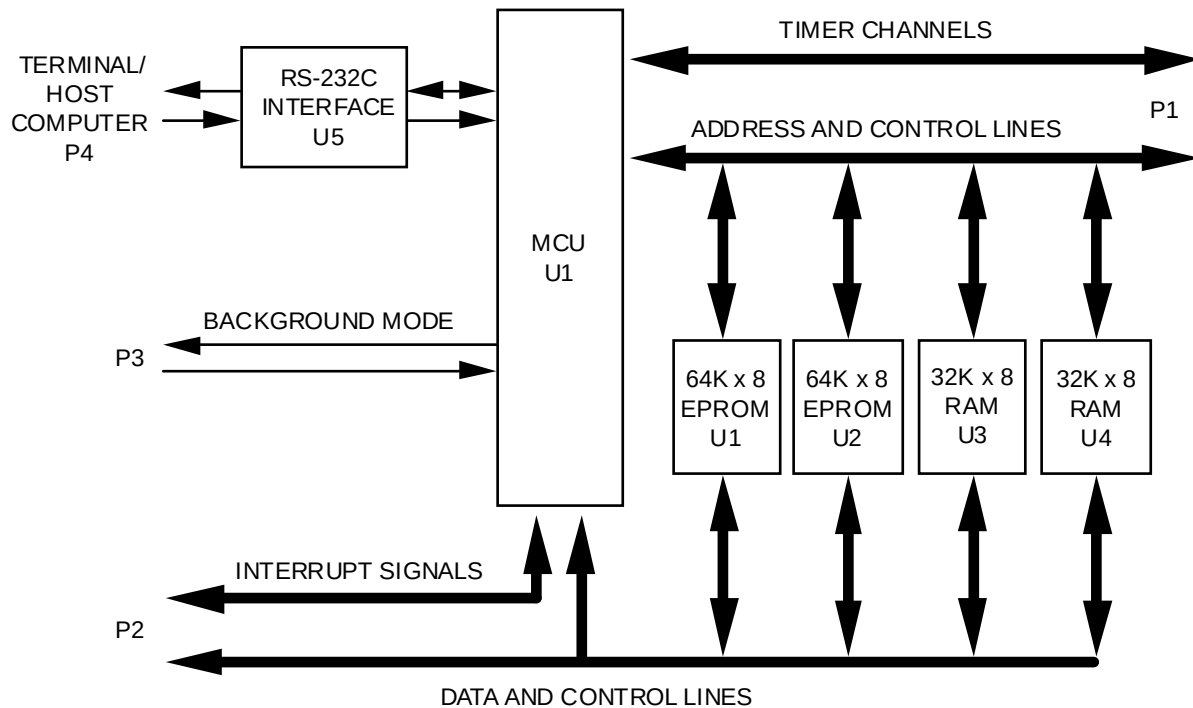


Figure 4-1. BCC Block Diagram

4.2.1 MCU

The resident MC68332 Microcontroller Unit (MCU) of the BCC provides resources for designing, debugging, and evaluating MC68332 MCU based target systems and simplifies user evaluation of prototype hardware/software products.

The MCU device is a 32-bit integrated microcontroller, combining high-performance data manipulation capabilities with powerful peripheral subsystems. The MCU includes:

- 32-bit central processor unit (CPU32)
- Time processor unit (TPU)
- Queued serial module (QSM)
- Random access memory (RAM)
- External bus interface
- Chip selects
- System clock
- Test module

4.2.1.1 32-Bit Central Processor Unit

The CPU32 is the central processor for the MC68332 MCU device. The CPU32 is source and object code compatible with the MC68000 and MC68010. All user programs can be executed unchanged. The CPU32 features are:

- 32-Bit internal data path and arithmetic hardware - 16-bit external data bus
- 32-Bit internal address bus - 24-bit external address bus
- Powerful instruction set
- Eight 32-bit general purpose data registers
- Seven 32-bit general purpose address registers
- Separate user and supervisor stack pointers and address spaces
- Separate program and data address spaces
- Flexible addressing modes
- Full interrupt processing

4.2.1.2 Time Processor Unit

The Time Processor Unit (TPU) optimizes performance of time-related activities. The TPU has a dedicated execution unit, tri-level prioritized scheduler, data storage RAM, dual time bases, and microcode ROM which drastically reduces the need for CPU intervention. The TPU controls sixteen independent, orthogonal channels; each channel has an associated I/O pin and can perform any time function. Each channel also contains a dedicated event register, for both match and input capture functions.

Each channel can be synchronized to either of two 16-bit, free-running counters with a pre-scaler. One counter, based on the system clock, provides resolution of TPU system clock divided by 4. The second counter, based on an external reference, also provides resolution of TPU system clock divided by 8. Channels may also be linked together, allowing the user to reference operations on one channel to the occurrence of a specified action on another channel, providing inter-task control.

4.2.1.3 Queued Serial Module

The QSM contains two serial ports. The queued serial peripheral interface (QSPI) port provides easy peripheral expansion or inter-processor communications via a full-duplex, synchronous, three-line bus: data-in, data-out, and a serial clock. Four programmable peripheral select pins provide address-ability for as many as 16 peripheral devices. A QSPI enhancement is an added queue in a small RAM. This lets the QSPI handle as many as 16 serial transfers of 8- to 16-bits each, or to transmit a stream of data as long as 256 bits without CPU intervention. A special wrap-around mode lets the user continuously sample a serial peripheral, automatically updating the QSPI RAM for efficient interfacing to serial peripheral devices (such as analog-to-digital converters).

The serial communications interface (SCI) port provides a standard non-return to zero (NRZ) mark/space format. Advanced error detection circuitry catches noise glitches to 1/16 of a bit time in duration. Word length is software selectable between 8- or 9-bits, and the SCI modulus-type, baud rate generator provides baud rates from 64 to 524k baud, based on a 16.77 MHz system clock. The SCI features full- or half-duplex operation, with separate transmitter and receiver enable bits and double buffering of data. Optional parity generation and detection provide either even or odd parity check capability. Wake-up functions let the CPU run uninterrupted until either a true idle line is detected or a new address byte is received.

4.2.1.4 Random Access Memory

2k bytes of static RAM are contained within the MC68332 MCU device. The RAM is used for storage of variable and temporary data. RAM data size may be 8-bits (byte), 16-bits (word), or 32-bits (longword). The RAM can be mapped to any 2k byte boundary in the address map.

4.2.1.5 External Bus Interface

The external bus consists of 24 address lines and a 16-bit data bus. The data bus allows dynamic sizing between 8- and 16-bit data accesses. A read-modify-write cycle (RMC) signal prevents bus cycle interruption. External bus arbitration is accomplished by a three-line handshaking interface.

4.2.1.6 Chip Selects

Twelve independently programmable chip selects provide fast, two-cycle external memory, or peripheral access. Block size is programmable from 2 kilobytes through 1 megabyte. Accesses can be selected for either 8- or 16-bit transfers. As many as 13 wait states can be programmed for insertion during the access. All bus interface signals are automatically handled by the chip select logic.

4.2.1.7 System Clock

An on-chip phase locked loop circuit generates the system clock signal to run the device up to 16.78 MHz from a 32.768 kHz watch crystal. The system speed can be changed dynamically, providing either high performance or low power consumption under software control. The system clock is a fully-static CMOS design, so it is possible to completely stop the system clock via a low power stop instruction, while still retaining the contents of the registers and on-board RAM.

4.2.1.8 Test Module

The test module consolidates the microcontroller test logic into a single block to facilitate production testing, user self-test, and system diagnostics. Scan paths throughout the MC68332 provide signature analysis checks on internal logic. User self-test is initiated by asserting the test pin to enter test mode. This test provides a pass/fail response to various externally supplied test vectors.

4.2.2 User Memory

On board the BCC is 32k x 16 bits of RAM and 64k x 16 bits of EPROM. The RAM is the debug monitor storage area and user accessible memory space; the M68CPU32BUG Debug Monitor is stored in the BCC EPROMs. For debug monitor functionality see the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1. Figure 4-3 is the EVK memory map.

The PFB has sockets for 32k x 16 or 64k x 16 bit RAM or 64k x 16 bit EPROM. The RAM and/or EPROM, supplied by the user, is user-accessible memory space.

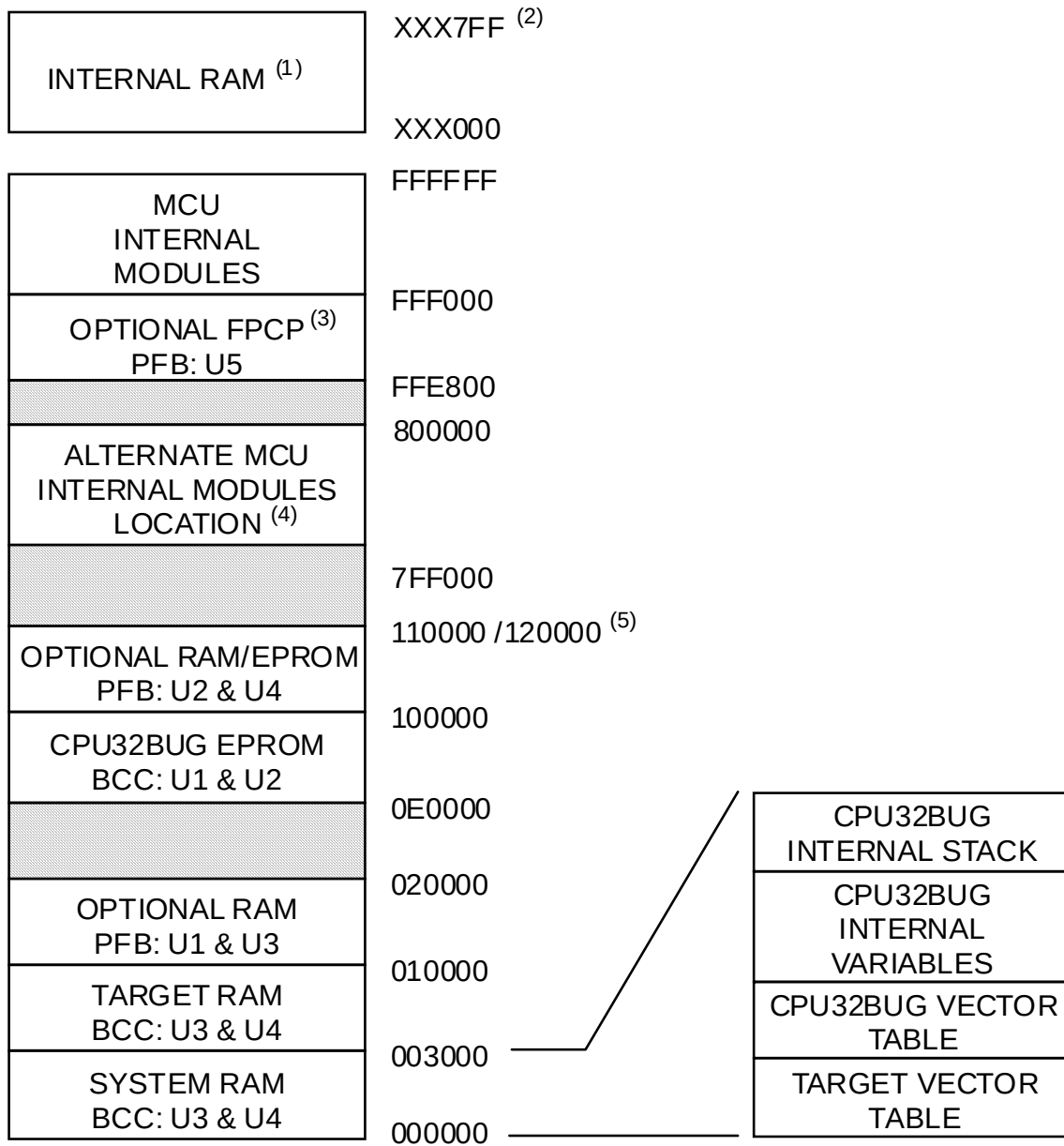
4.2.3 Terminal and Host Computer I/O Port

The MC68332 MCU serial communication interface pins drive levels are 0 and 5 Vdc. An interface device (U5) translates these voltage levels to +/-10 Vdc, sufficient to allow RS-232C communications.

The RS-232C serial communication port P4 facilitates terminal and host computer interconnection. If a host computer is used a terminal emulation package (PCKERMIT.EXE, PROCOMM, MacTerminal, White Knight, etc.) must be utilized. Chapter 5 contains a description of P4 pin assignments.

4.2.4 Background Mode Interface Port

The background debug mode is implemented in MCU microcode. In background mode, registers can be viewed or altered, memory can be read or written, and test features can be executed. Background mode is initiated by one of several sources: externally generated breakpoints, internal peripherally generated breakpoints, software, and catastrophic exception conditions. Instruction execution is suspended for the duration of background mode. Background mode communications between the BCC and the development system are via a serial link (P3).



1. Consult the MCU device user's manual.
2. XXbase address is user programmable. Internal modules, such as internal RAM, can be configured on power-up/reset by using the initialization table (INITTBL) covered in Appendix C of the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1.
3. Floating point coprocessor - MC68881/MC68882.
4. See Appendix C of the M68CPU32BUG Debug Monitor User's Manual, M68CPU32BUG/AD1.
5. Depends on the memory device type used.

Figure 4-2. BCC Memory Map

CHAPTER 5

SUPPORT INFORMATION

5.1 INTRODUCTION

This chapter provides the connector signal descriptions.

5.2 CONNECTOR SIGNAL DESCRIPTIONS

Connectors P1 and P2 connect the BCC to a target system. Connector P3 is for background mode. Connector P4 is for serial communication between the BCC and a host computer.

Pin assignments for P1, P2, P3 and P4 are defined in Tables 5-1 through 5-4. Connector signals are identified by pin number, signal mnemonic, and signal name and description.

Table 5-1. P1 Expansion Connector Pin Assignments

Pin Number	Signal Mnemonic	Signal Name And Description
1, 2	GND	GROUND
3, 4	+5V	SYSTEM POWER SUPPLY – +5 volt power source.
5	DTR0UT	DATA TERMINAL READY – RS-232C handshake from the BCCDI.
6 — 24	A0 — A18	ADDRESS BUS – Three-state output address bus.
25	NC	No Connection
26	NC	No Connection
27	+13—24V DI	+13—24 VOLTS DEVELOPMENT INTER-FACE – BCCDI switching voltage.

Table 5-1. P1 Expansion Connector Pin Assignments (continued)

Pin Number	Signal Mnemonic	Signal Name And Description
28	VSTBY	VOLTAGE STANDBY – Input standby voltage source for MCU on-chip RAM.
29	+13—24V DI	+13—24 VOLTS DEVELOPMENT INTERFACE – BCCDI switching voltage.
30	T2CLK	TPU CLOCK – External input clock source to the TPU.
31 — 46	TP15 — TP0	TIME PROCESSOR UNIT CHANNELS – TPU Input/output channels.
47	MOSI	MASTER-OUT SLAVE-IN – Serial output from the OSPI in master mode, and serial input to the QSPI in slave mode.
48	MISO	MASTER-IN SLAVE-OUT – Serial input to the QSPI in master mode, and serial output from the QSPI in slave mode.
49	$\overline{\text{PCS0}}$ / $\overline{\text{SS}}$	PERIPHERAL CHIP SELECT 0 – Active-low output QSPI peripheral chip select signal. SLAVE SELECT – Bi-directional active-low signal that places the QSPI in slave mode.
50	SCK	QSPI SERIAL CLOCK – Input/output QSPI clock source.
51	$\overline{\text{PCS2}}$	PERIPHERAL CHIP SELECT 2 – Active-low output QSPI peripheral chip select.
52	$\overline{\text{PCS1}}$	PERIPHERAL CHIP SELECT 1 – Active-low output QSPI peripheral chip select.
53	TXD	TRANSMIT DATA – Serial data output line.
54	$\overline{\text{PCS3}}$	PERIPHERAL CHIP SELECT 3 – Active-low output QSPI peripheral chip select.

Table 5-1. P1 Expansion Connector Pin Assignments (continued)

Pin Number	Signal Mnemonic	Signal Name And Description
55	$\overline{\text{BKPT}}$ /	BREAKPOINT – An active-low input signal that places the CPU32 in background debug mode.
	DSCLK	DEVELOPMENT SYSTEM CLOCK – Serial input clock for background debug mode.
56	RXD	RECEIVE DATA – Serial data input line.
57	$\overline{\text{RESET}}$	RESET – Active-low input/output signal for initiating a system reset.
58	FREEZE /	FREEZE – Output signal that indicates that the CPU32 has entered background debug mode.
	QUOT	QUOTIENT OUT – Output signal that furnishes the quotient bit of the polynomial divider for test purposes.
59	$\overline{\text{IPIPE}}$ /	INSTRUCTION PIPE – Active-low output signal used to track movement of words through the instruction pipeline.
	DSO	DEVELOPMENT SERIAL OUT – Serial output for background debug mode.
60	$\overline{\text{IFETCH}}$ /	INSTRUCTION FETCH – Active-low output signal that indicates when the CPU is performing an instruction word pre-fetch and when the instruction pipeline has been flushed.
	DSI	DEVELOPMENT SERIAL IN – Serial data input for background debug mode.
61, 62	+5V	+5 VOLT INPUT POWER
63, 64	GND	GROUND

Table 5-2. P2 Expansion Connector Pin Assignments

Pin Number	Signal Mnemonic	Signal Name And Description
1, 2	GND	GROUND
3, 4	+5V	+5 VOLT INPUT POWER
5 — 20	D0 — D15	DATA BUS – 16 bi-directional data pins.
21	RXD DI	RECEIVE DATA DEVELOPMENT INTER-FACE – BCCDI receive data.
22	TXD DI	TRANSMIT DATA DEVELOPMENT INTER-FACE – BCCDI transmit data.
23	MODB DI	MODE B DEVELOPMENT INTERFACE – BCCDI mode B.
24	XMT 232	TRANSMIT DATA – Serial data output signal.
25	$\overline{\text{CSBOOT}}$	BOOT CHIP SELECT – An active-low output chip select.
26	RCV 232	RECEIVE DATA – Serial data input signal.
27	$\text{R}/\overline{\text{W}}$	READ/WRITE – Active-high output signal that indicates the direction of data transfer on the bus.
28	MODCK	CLOCK MODE SELECT – Active-high input signal that selects the source of the internal system clock.
29	$\overline{\text{TSTME}}$ / TSC	TEST MODE ENABLE – Active-low input signal that is a hardware enable for test mode. THREE STATE CONTROL – When TSC is 8 volts (1.6 X +5V), this input signal forces all output drivers to a high-impedance state.
30 — 34	$\overline{\text{A23/CS10}}$, $\overline{\text{A22/CS9}}$, $\overline{\text{A21/CS8}}$, $\overline{\text{A20/CS7}}$, $\overline{\text{A19/CS6}}$	ADDRESS BUS 19—23 – Three-state output address bus. CHIP SELECTS 6—10 – Output signals that select peripheral/memory devices at programmed addresses.

Table 5-2. P2 Expansion Connector Pin Assignments (continued)

Pin Number	Signal Mnemonic	Signal Name And Description
35 — 37	$\overline{FC2}/\overline{CS5}$, $\overline{FC1}/\overline{CS4}$, $\overline{FC0}/\overline{CS3}$	FUNCTION CODES – Three-state output signals that identify the processor state and address space of the current bus cycle. CHIP SELECTS 3—5 – Output signals that select peripheral/memory devices at programmed addresses.
38	$\overline{BGACK}$ / $\overline{CS2}$	BUS GRANT ACKNOWLEDGE – Active-low input signal that indicates that an external device has assumed control of the bus. CHIP SELECT 2 – Output signal that selects peripheral/ memory devices at programmed addresses.
39	$\overline{BG}$ / $\overline{CS1}$	BUS GRANT – Active-low output signal that indicates that the current bus cycle is complete and the MC68332 has relinquished the bus. CHIP SELECT 1 – Output signal that selects peripheral/ memory devices at programmed addresses.
40	$\overline{BR}$ / $\overline{CS0}$	BUS REQUEST – Active-low input signal that indicates that an external device requires bus master-ship. CHIP SELECT 0 – Output signal that selects peripheral/ memory devices at programmed addresses.
41 — 47	$\overline{IRQ1} — \overline{IRQ7}$	INTERRUPT REQUEST (1—7) – Seven active-low input lines used to request MCU synchronous interrupts. IRQ7 has the highest priority.
48	$\overline{BERR}$	BUS ERROR – Active-low input signal that indicates that an erroneous bus operation is being attempted.

Table 5-2. P2 Expansion Connector Pin Assignments (continued)

Pin Number	Signal Mnemonic	Signal Name And Description
49, 50	$\overline{\text{DSACK0}}, \overline{\text{DSACK1}}$	DATA AND SIZE ACKNOWLEDGE – Active-low input signals that allow asynchronous data transfers and dynamic bus sizing between the MC68332 and external devices.
51	$\overline{\text{AVEC}}$	AUTOVECTOR – Active-low input signal that requests an automatic vector during an interrupt acknowledge cycle.
52	$\overline{\text{RMC}}$	READ-MODIFY-WRITE CYCLE – Active-low output signal that identifies the bus cycle as part of an indivisible read-modify-write operation.
53	$\overline{\text{DS}}$	DATA STROBE – Active-low output signal, that during a read cycle, indicates that an external device should place valid data on the data bus. During the write cycle, DS indicates that valid data is on the data bus.
54	$\overline{\text{AS}}$	ADDRESS STROBE – Active-low output signal that indicates that a valid address is on the address bus.
55, 56	SIZ0, SIZ1	TRANSFER SIZE – Active-low output signals that indicate the number of bytes remaining to be transferred during this cycle.
57	$\overline{\text{11RESET}}$	Not connected.
58	CLKOUT	SYSTEM CLOCK OUT – Output signal that is the MC68332 internal system clock.
59	EXTAL	EXTERNAL CLOCK INPUT – External clock input for the MC68332 MCU device.
60	$\overline{\text{HALT}}$	HALT – Active-low input/output signal that suspends <u>external</u> bus activity, to request a retry when used with BERR, or for single-step operation.
61, 62	+5V	+5 VOLT INPUT POWER
63, 64	GND	GROUND

Table 5-3. J8 Background Mode Connector Pin Assignments

Pin Number	Signal Mnemonic	Signal Name And Description
1	$\overline{DS}$	DATA STROBE – Active-low output signal, that during a read cycle, indicates that an external device should place valid data on the data bus. During the write cycle, DS indicates that valid data is on the data bus.
2	$\overline{BERR}$	BUS ERROR – Active-low input signal that indicates that an erroneous bus operation is being attempted.
3	GND	GROUND
4	$\overline{BKPT}$ / DSCLK	BREAKPOINT – An active-low input signal that places the CPU32 in background debug mode. DEVELOPMENT SYSTEM CLOCK – Serial input clock for background debug mode.
5	GND	GROUND
6	FREEZE / QUOT	FREEZE – Output signal that indicates that the CPU32 has entered background debug mode. QUOTIENT OUT – Output signal that furnishes the quotient bit of the polynomial divider for test purposes
7	$\overline{RESET}$	RESET – Active-low input/output signal for initiating a system reset.
8	$\overline{IFETCH}$ / DSI	INSTRUCTION FETCH – Active-low output signal that indicates when the CPU is performing an instruction word pre-fetch and when the instruction pipeline has been flushed. DEVELOPMENT SERIAL IN – Serial data input for background debug mode.
9	+5V	+5 VOLT INPUT POWER
10	$\overline{IPIPE}$ / DSO	INSTRUCTION PIPE – Active-low output signal used to track movement of words through the instruction pipeline. DEVELOPMENT SERIAL OUT – Serial output for background debug mode.

Table 5-4. J9 RS-232C Serial Communication Connector Pin Assignments

Pin Number	Signal Mnemonic	Signal Name And Description
1	XMIT	TRANSMIT DATA – RS-232C serial output data.
2	GND	GROUND
3	RCV	RECEIVE DATA – RS-232C serial input data.
4	+10V	+10 VOLTS DC – Output voltage that may be used to drive RS-232C handshake lines.

APPENDIX A

S-RECORD INFORMATION

The S-record format for output modules was devised for the purpose of encoding programs or data files in a printable format for transportation between computer systems. The transportation process can thus be visually monitored and the S-records can be more easily edited.

S-RECORD CONTENT

When viewed by the user, S-records are essentially character strings made of several fields which identify the record type, record length, memory address, code/data and checksum. Each byte of binary data is encoded as a 2-character hexadecimal number; the first character representing the high-order 4 bits, and the second the low-order 4 bits of the byte.

The five fields which comprise an S-record are shown below:

TYPE	RECORD LENGTH	ADDRESS	CODE/DATA	CHECKSUM
------	---------------	---------	-----------	----------

Where the fields are composed as follows:

Field	Printable Characters	Contents
type	2	S-records type -- S0, S1, etc.
record length	2	The count of the character pairs in the record, excluding type and record length.
address	4,6,or 8	The 2-, 3-, or 4-byte address at which the data field is to be loaded into memory.
code/data	0-n	From 0 to n bytes of executable code, memory-loadable data, or descriptive information. For compatibility with teletypewriters, some programs may limit the number of bytes to as few as 28 (56 printable characters in the S-record).
checksum	2	The least significant byte of the one's complement of the sum of the values represented by the pairs of characters making up the records length, address, and the code/data fields.

Each record may be terminated with a CR/LF/NULL. Additionally, an S-record may have an initial field to accommodate other data such as line numbers generated by some time-sharing systems. An S-record file is a normal ASCII text file in the operating system of origin.

Accuracy of transmission is ensured by the record length (byte count) and checksum fields.

S-RECORD TYPES

Eight types of S-records have been defined to accommodate the several needs of the encoding, transportation and decoding functions. The various Motorola upload, download and other records transportation control programs, as well as cross assemblers, linkers and other file-creating or debugging programs, utilize only those S-records which serve the purpose of the program. For specific information on which S-records are supported by a particular program, the user's manual for the program must be consulted. 332Bug supports S0, S1, S2, S3, S7, S8, and S9 records.

An S-record format module may contain S-records of the following types:

Type	Description
S0	The header record for each block of S-records, The code/data field may contain any descriptive information identifying the following block of S-records. The address field is normally zeros.
S1	A record containing code/data and the 2-byte address at which the code/data is to reside.
S2	A record containing code/data and the 3-byte address at which the code/data is to reside.
S3	A record containing code/data and the 4-byte address at which the code/data is to reside.
S5	A record containing the number of S1, S2, and S3 records transmitted in a particular block. This count appears in the address field. There is no code/data field.
S7	A termination record for a block of S3 records, The address field may optionally contain the 4-byte address of the instruction to which control is passed. There is no code/data field.
S8	A termination record for a block of S2 records. The address field may optionally contain the 3-byte address of the instruction to which control is passed. There is no code/data field.
S9	A termination record for a block of S1 records. The address field may optionally contain the 2-byte address of the instruction to which control is passed. If not specified, the first entry point specification encountered in the object module input will be used. There is no code/data field.

Only one termination record is used for each block of S-records. S7 and S8 records are usually used only when control is to be passed to a 3 or 4 byte address. Normally, only one header record is used, although it is possible for multiple header records to occur.

S-RECORDS CREATION

S-record format files may be produced by dump utilities, debuggers, linkage editors, cross assemblers or cross linkers. Several programs are available for downloading a file in S-record format from a host system to a microprocessor-based system.

EXAMPLE

Shown below is a typical S-record format module, as printed or displayed:

```
S00600004844521B
S1130000285F245F2212226A000424290008237C2A
S11300100002000800082629001853812341001813
S113002041E900084E42234300182342000824A952
S113003000144ED492
S9030000FC
```

The module consists of one S0 record, four S1 records, and an S9 record.

The S0 record is comprised of the following character pairs:

S0	S-record type S0, indicating that it is a header record.
06	Hexadecimal 06 (decimal 6), indicating that six character pairs (or ASCII bytes) follow.
00	Four-character, 2-byte, address field; zeros in this example.
00	
48	
44	ASCII H, D and R - "HDR".
52	
1B	The checksum.

The first S1 record is explained as follows:

S1	S-record type S1, indicating that it is a code/data record to be loaded/verified at a 2-byte address.
13	Hexadecimal 13 (decimal 19), indicating that 19 character pairs, representing 19 bytes of binary data, follow.
00	Four-character, 2-byte, address field; hexadecimal address 0000, where the data which follows is to be loaded.
00	

The next 16 character pairs of the first S1 record are the ASCII bytes of the actual program code/data. In this assembly language example, the hexadecimal opcodes of the program are written in sequence in the code/data fields of the S1 records:

<u>OPCODE</u>	<u>INSTRUCTION</u>
285F	MOVE.L (A7)+,A4
245F	MOVE.L (A7)+,A2
2212	MOVE.L (A2),D1
226A0004	MOVE.L 4(A2),A1
24290008	MOVE.L FUNCTION(A1),D2
237C	MOVE.L #FORCEFUNC,FUNCTION(A1)

(The balance of this code is continued in the code/data fields of the remaining S1 records and stored in memory.)

2A The checksum of the first S1 record.

The second and third S1 records also each contain \$13 (19) character pairs and are ended with checksums 13 and 52 respectively. The fourth S1 record contains 07 character pairs and has a checksum of 92.

The S9 record is explained as follows:

S9 S-record type S9, indicating that it is a termination record.
 03 Hexadecimal 03, indicating that three character pairs (3 bytes) follow.
 00
 00 The address field, zeros.
 FC The checksum of the S9 record.

Each printable character in an S-record is encoded in a hexadecimal (ASCII in this example) representation of the binary bits which are actually transmitted. For example, the first S1 record above is sent as:

TYPE				LENGTH				ADDRESS								CODE/DATA								CHECKSUM					
S 1				1 3				0 0 0 0								2 8 5 F ...								2 A					
5 3		3 1		3 1		3 3		3 0		3 0		3 0		3 0		3 2		3 8		3 5		4 6		...		3 2		4 1	
0101	0011	0011	0001	0011	0001	0011	0011	0011	0000	0011	0000	0011	0000	0011	0000	0011	0010	0011	1000	0011	0101	0100	0110	...	0011	0010	0100	0001	